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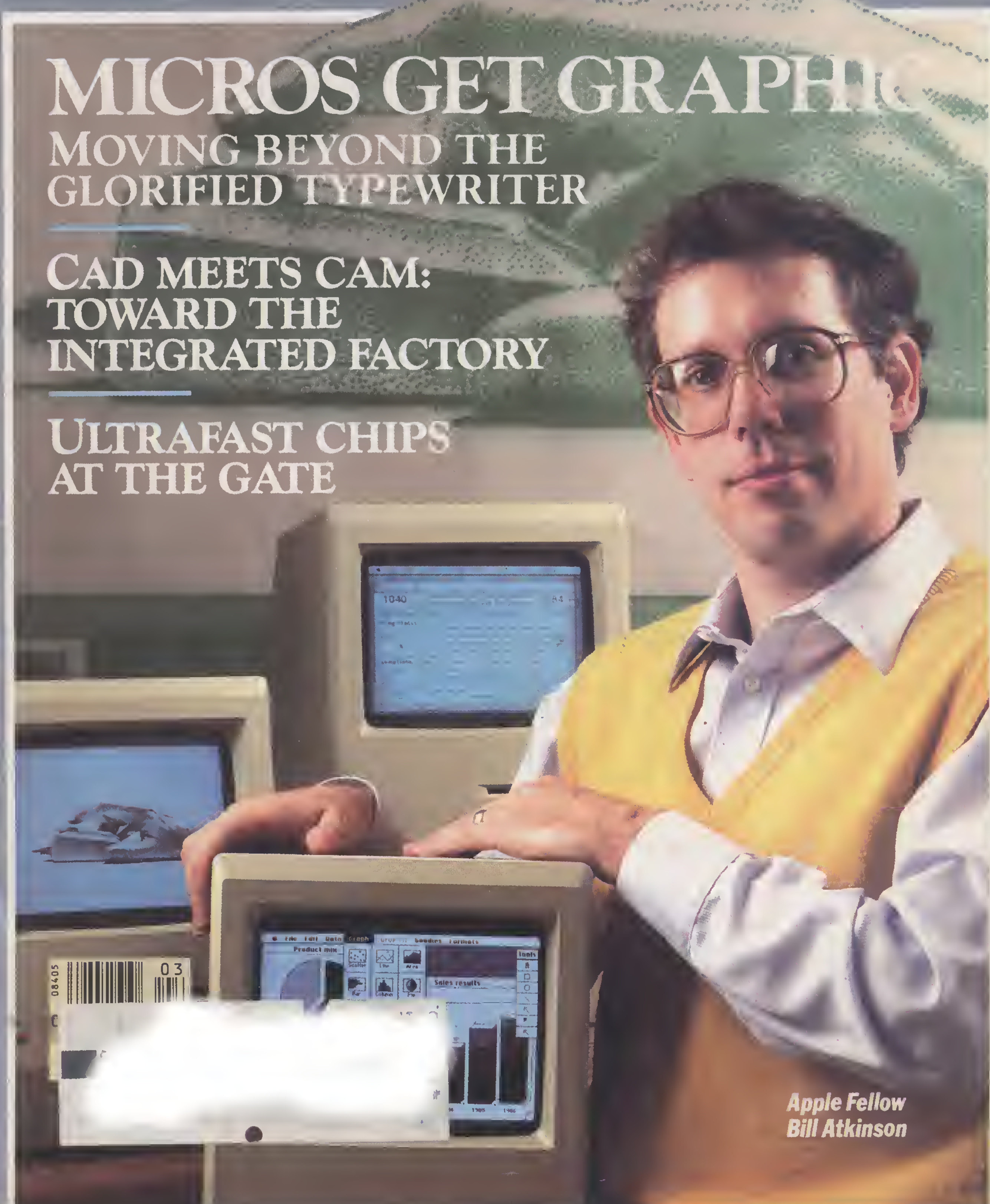

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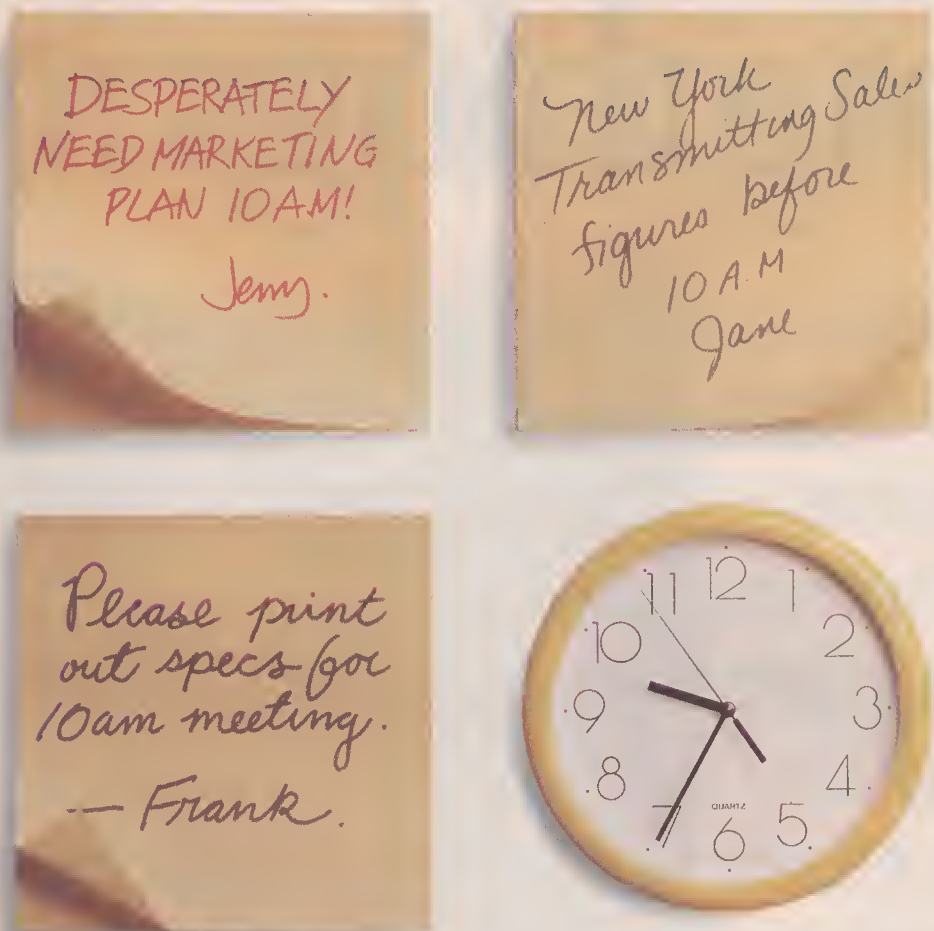

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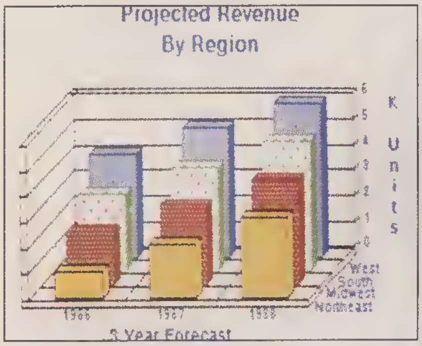

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FEATURES

DEPARTMENTS

Cover Bill Atkinson shows software using his QuickDraw graphics format: Atkinson's MacPaint (hand on mouse), MacInTax from Softview (tax form), and Cricket Graph from Cricket Software (business graphics). Photograph by John McDermott.

OPINION

LOIS LEONARD STOCK

Correcting the mess in military procurement

The nation has gone along with President Reagan's effort to boost military spending in order to strengthen defenses. But the public has a right to demand that tax money be spent wisely. What bothers even long-time military supporters is that the weaknesses of the procurement system have become so ingrained that pumping in more money may be increasing waste rather than buying more readiness and military strength. Even stalwart military backers like senators Barry Goldwater (R-Ariz.) and Sam Nunn (D-Ga.) are calling for sweeping changes.

The general press has focused on symptoms rather than underlying causes. Headlines cite excessive costs for spare parts and tools, or coffee pots and toilet seats. They trumpet charges of personal gifts, hunting trips, and nonbusiness flights, or they reveal overbilling based on fraud. This makes lively copy and grabs attention on the evening news, but it misses the central issue: Military contracting, particularly for advanced technology systems, is long overdue for a basic overhaul.

A new management structure at the top is necessary to focus on total national defense needs rather than the parochial interests of individual services. Priorities must be set for the entire defense system, rather than separately for each service.

Military procurement must become more businesslike. How many companies would give a contract to the lowest bidder and then allow overruns that might double the agreed-on costs? How many businesses would operate by micromanagement of projects, using monstrous lists of detailed specifications that increase paperwork and costs but don't ensure that equipment will meet functional requirements? Contracting should be based on clearly defining what is needed, and then having vendors provide warranties that their systems will perform reliably in the field. Vendors should be given adequate opportunities to test their designs and to correct and improve them, but they should face financial penalties if their equipment doesn't do the job.

The legislative branch should be forging solutions, but too often it is part of the problem. Large contractors have learned how to apply political leverage so that procurement decisions are influenced by congressional infighting. Congressmen must recognize that sound decisions made by well-trained and qualified contracting officers will get lots more bang for the buck.

Let's stop wailing about the system. Let's fix it. If Congress truly represents the people, then it must correct the structural deficiencies that make military contracting ineffective.

Robert Haavind

Robert Haavind

highTechnology

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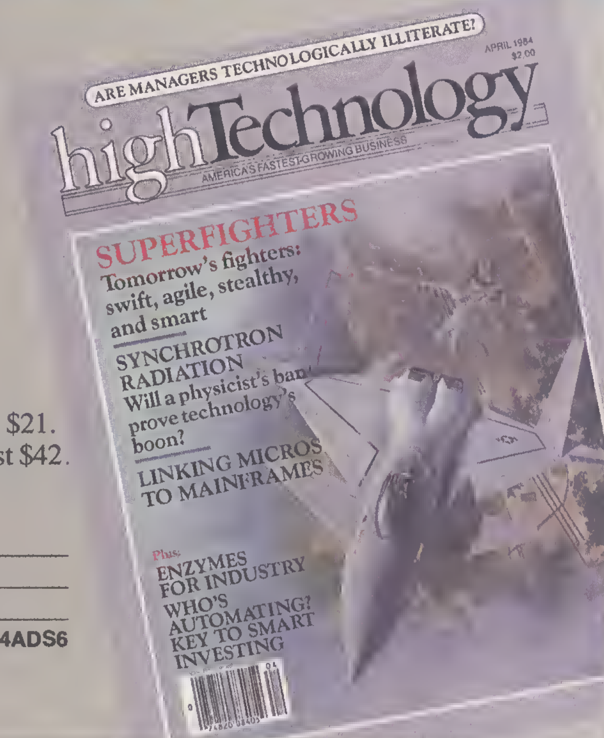

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metal pumping system to assist in the recycling of aluminum-cans.

has been the development of melting techniques that are five to ten times faster than conventional technologies. Alcoa researchers have been issued four patents covering molten metal pumping and skim removal. We are also initiating major new technical programs we feel will reduce the costs of recycling even further.

P. R. Bridenbaugh, Vice-President
Research and Development
Alcoa Laboratories
Alcoa Center, Pa.

Thomas O. Gray, Executive Director
American Wind Energy Assoc.
Alexandria, Va.

Not a think tank

While we were flattered by the recent profile of Repligen in "Biotechnology for hire" (Dec. 1985, p. 71), we must correct the implication that the company is an ivory-tower think tank. Not only do we plan to manufacture biotechnology products for industries such as agriculture and pulp and

We welcome comments from our readers. Please address letters to Editor, High Technology, 38 Commercial Wharf, Boston, MA 02110.

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LOIS LEONARD-STOCK

LETTERS

Aluminum recycling: can do

Your article "A renaissance in recycling" (Oct. 1985, p. 32), was certainly appropriate, but it did not include what is perhaps the most successful recycling story of the past decade.

The striking growth in aluminum-can recycling—from 3 million pounds in 1970 to well over a billion pounds in 1984—challenged technologists at Alcoa to develop cost-effective recycling technologies for massive volumes of scrap.

A major accomplishment, for example, has been the development of melting techniques that are five to ten times faster than conventional technologies. Alcoa researchers have been issued four patents covering molten metal pumping and skim removal. We are also initiating major new technical programs we feel will reduce the costs of recycling even further.

Alcoa developed a high-speed molten metal pumping system to assist in the recycling of aluminum-cans.

P. R. Bridenbaugh, Vice-President
Research and Development
Alcoa Laboratories
Alcoa Center, Pa.

Nothing new under the sun

Regarding "Loudspeakers: in search of higher fi" (June 1985, p. 51), did you know that a ribbon loudspeaker called an Electrostat was manufactured thirty years ago? The sound quality was rated very highly by Consumers Union. I am still using the pair I purchased back then.

William Goodstein
Woodbridge, Conn.

Pointing a finger at nuke management

Nicholas Baran's letter, "When nuclear consultants go overboard" (Dec. 1985, p. 5), is arrant nonsense—a familiar case of industry trying to shift the blame [for cost overruns in nuclear-power plant construction] to the government.

The blame really lies with the utilities' management and engineers. It is not a matter of waking up one morning to find that there has been a billion-dollar overrun. Sloppy management loves to build new stations—the cost is the public's.

Alan R. Moore
Parma, Mich.

Correcting for wind

I commend you for portraying the growth of the wind-energy industry and the problems it faces with the impending loss of federal tax incentives in "Is wind power gone with the tax credits?" (Jan. 1986, p. 17). However, I regretfully deny having singled out any particular wind company as being financially stronger than others. As executive director of the industry's trade association, it would be inappropriate for me to make such a statement.

Thomas O. Gray, Executive Director
American Wind Energy Assoc.
Alexandria, Va.

Not a think tank

While we were flattered by the recent profile of Repligen in "Biotechnology for hire" (Dec. 1985, p. 71), we must correct the implication that the company is an ivory-tower think tank. Not only do we plan to manufacture biotechnology products for industries such as agriculture and pulp and paper, but 20% of our current revenues comes from product sales. This record is rare in our industry and reflects our orientation to markets and products, rather than to technology for its own sake.

Steven James Lee, President
Repligen Corp.
Cambridge, Mass.

Golden gloves

I found your editorial "How to meet the foreign challenge: put customers first" (Oct. 1985, p. 4) both interesting and accurate. It should be required reading for all businesspeople.

Our key to success, we believe, is a genuine sensitivity to our customers' needs.

The U.S. glove manufacturing industry has been heavily affected by imports, yet the expansion and profitability of Golden Needles remains a matter of record. We get to know our customers and we listen to them.

Daniel M. Nathan, Sales Manager
Golden Needles Knitting & Glove Co.
Wilkesboro, N.C.

Scientific word processors

In "Tools for manipulating symbols" (Feb., 1986,. p. 57)—which dealt with scientific and professional word processing—the company list was inadvertently omitted:

Addison-Wesley, Educational Media Systems Division (MicroTeX), Reading, MA 01867, (617) 944–3700

Icon Technology (MacAuthor), 9 Jarrom St., Leicester LE27DH, England, 0533–546 225

Lexisoft (Spellbinder Scientific), PO Box 1378, Davis, CA 95617, (916) 758–3630

Lifetree Software (Volkswriter Scientific), 411 Pacific St., Monterey, CA 93940, (408) 373–4718

Personal TeX, 20 Sunnyside, Suite H, Mill Valley, CA 94941, (415) 388-8853

Scientific Communications Corp. (Scientex), 2136 Locust St., Philadelphia, PA 19103, (215) 732–7978

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Triad Computing (T3), 1190-B Foster Rd., Las Cruces, NM 88001, (800) 874–2383

We welcome comments from our readers. Please address letters to Editor, High Technology, 38 Commercial Wharf, Boston, MA 02110.

One of the many examples of Ford's attention to detail is the cargo restraining net on the LX. It helps keep grocery bags from tipping over and loose packages from sliding around.

THE NEW F
ITS PERFORMA
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The mark of a well-designed automobile is total performance.

In the case of Taurus, that means a powerful 3-liter, V-6 engine. Plus dozens of other features that not only respond to the needs of the driver, but to those of the passengers as well.

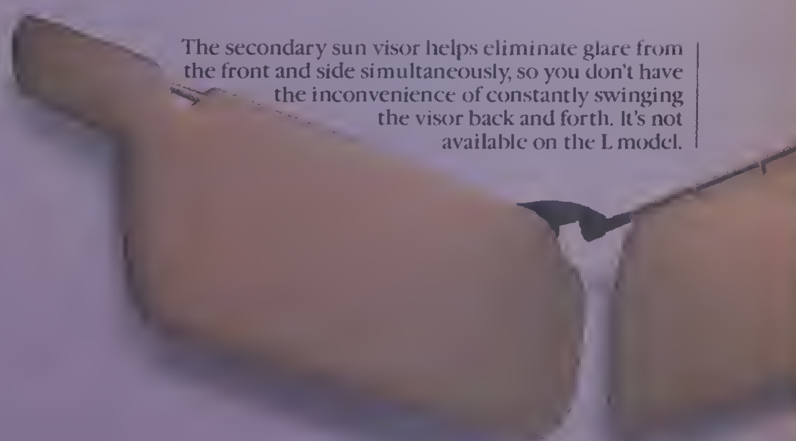
As a result, Taurus performs beautifully.

Even the smallest details have been carefully thought out. For example, the shape of this light switch and its position on the instrument panel make the simple task of turning on the lights as easy as possible.

The trip computer is part of the optional electronic instrument cluster. It provides valuable travel information such as rate of fuel consumption and the distance you can travel until empty.

The optional electronic instrument panel is designed to be "user friendly." All instruments are easy to read and all controls are placed where your hands can easily find them.

RD TAURUS. ICE ISN'T LIMITED DER THE HOOD.



The secondary sun visor helps eliminate glare from the front and side simultaneously, so you don't have the inconvenience of constantly swinging the visor back and forth. It's not available on the L model.

Right down to the smallest detail.

The best-built American cars.

At Ford, Quality is Job 1. A 1985 survey established that Ford makes the best-built American cars. This is based on an average number of problems reported by owners in a six-month period on 1981-1984 models designed and built in the U.S.

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But don't think for a moment that New Jersey is a newcomer to high technology. It has long held the distinction of having the nation's fourth highest concentration of high-tech firms. It also ranks fourth nationally in R&D expenditures. And there are more than 100,000 scientists and researchers in New Jersey, the highest per capita in the country.

Advanced Technology Centers

Already a leader in collaborative academic-industrial research efforts, New Jersey is now establishing five "world class" centers at leading universities to stimulate even closer relationships. The centers — which may be fully operational within three years — will be in the fields of biotechnology and medicine, telematics, industrial ceramics, food processing, and hazardous waste management. They will elevate the quality of research in New Jersey to a new high!

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New Jersey's high-tech leadership was further enhanced by the National Science Foundation's selection of Princeton University as the site for the world's most powerful supercomputer. One hundred times faster than any supercomputer now in use, it will have an incalcuable effect upon scientific research, as well as New Jersey's star-bright high-tech future.

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UPDATE

Pilots can receive weather graphics via TABS.

Climate controller takes the heat off utilities

An innovative way to heat and cool homes could lower peak electrical demand and thus reduce the need for utilities to add new generating capacity. The microprocessor-equipped Max system, developed by UHR Corp. (Alexandria, Va.), runs its heat pump and resistance heater only during times of day when electricity demand is lowest, typically midnight to 6 a.m. The heat produced is transferred to water in a storage tank. During the day, the water circulates to warm the house. In summertime the heat pump works through the night to cool the water, taking a load off the air conditioner during the day. As a pilot test, Max systems have been working for more than a year in 12 northern Virginia homes.

UHR announced its marketing plans in December, bringing a favorable response from many utilities, including Virginia Power (which collaborated on development), the Tennessee Valley Authority, and Southern California Edison. Company president C. W. Uhr contends that it will be cheaper for utilities to subsidize the purchase of Max systems than to build the new plants that would otherwise be needed.

For the consumer, Max should result in lower electric bills, since participating power companies will most likely discount off-peak electricity. The system also improves comfort. As the mercury dips below freezing, heat pumps by themselves approach their limit and blow air that is only slightly warmer than the room, creating drafts. In contrast, Max draws on the hot stored water to produce a more comfortable airstream.

Videotex plans flight paths

A computer-based service called TABS (Total Aviation Briefing Service) automatically plots flight plans for corporate and private pilots and provides them with information once available only to major airlines. Using either special terminals in airports or their own PCs, pilots enter their starting point and time, type of aircraft, and destination. They then receive a choice of routes. One provides maximum fuel economy, another the fastest flight time, a third the best weather conditions, and so on. TABS draws maps on screen using NAPLPS videotex graphics (the North American standard) to display weather and navigational information and warn of unusual conditions such as runway closings. Developed by World Weatherwatch (Markham, Ont.), TABS is marketed in the U.S. by Aviotex (Costa Mesa, Cal.).

Pilots can access TABS from about 40 airports in Ontario, Quebec, Alberta, Manitoba, Illinois, Florida, and California. Normally, use over the first hour costs 50¢ a minute, but many airports are offering it free as a promotion. Alternately, pilots who own NAPLPS terminal software for their own PCs can buy $30/month subscriptions, which include one hour's use per month. Although TABS was designed for private and corporate pilots whose planes must fly through, rather than over, weather, virtually all major North American passenger airlines are considering it as an addition to the briefing services they already provide their pilots.

A new tool for fighting blood clots

Protein C, an important regulator of blood clotting, was recently produced for the first time by genetic engineering. The developer, Integrated Genetics (Framingham, Mass.), plans to start clinical trials within two years. Commercialization, expected by 1989, could lead to worldwide annual sales of more than $200 million, says the company.

Normally produced by the liver, protein C helps maintain the delicate balance between clot formation and dissolution. Failure of the first mechanism could result in excessive bleeding after an injury; failure of the second could cause dangerous, blood-damming clots in the circulatory system. The biological activity of the new protein—made by inserting the human gene responsible for it into bacteria—is said to approach that of the natural chemical. It will probably be targeted to patients at risk for blood clots because of congenital or acquired protein C deficiency; the latter group includes postsurgical patients and those with liver disease or a deficiency of vitamin K (another chemical that affects clotting). The protein could also be used in conjunction with tissue plasminogen activator—a clot-dissolving enzyme that has been genetically engineered by Integrated Genetics and other biotechnology firms—in treating heart disease.

Protein C will be marketed in Europe and the U.S. by Knoll (the pharmaceutical subsidiary of West Germany's BASF), which will also conduct clinical trials.

ers practice the art of decision making.

Manufacturers must face the music

Jacques Koppel
Director, Technology Management Center
Philadelphia, Pa.

Technologies such as robots, lasers, sensors, machine vision, and computer-aided design have been hailed as the principal means for helping American manufacturers become more competitive in world markets. But U.S. industry has actually done very little modernization; it is largely ignoring the advanced technologies that could improve productivity, quality, and market share. Despite the lip service, it remains mired in antiquated manufacturing techniques.

That is what the Philadelphia-based Technology Management Center concluded after an 18-month study of 90 small and medium-sized Pennsylvania companies—of which 42 were actually visited—in the machine tool, electronic component, and medical device industries. We found that for most manufacturers, the "factory of the future" is still an incomprehensible concept. In fact, only 10% of the firms had any plan for introducing computers or other forms of advanced technology into their companies. And unlike marketing or financial plans, which most firms generate annually, these "technology plans" were seldom formalized.

The problem is not one of availability. It's that the new manufacturing technologies intimidate and confuse most managers, who thus resist adopting them. Even when these technologies are acquired, management is usually ill prepared to implement them effectively.

Compounding the problem is the reality that these technologies are computer-based, and managers and engineers schooled in another era often find them baffling. They have difficulty identifying the type of system that could most benefit their operations. And even if a firm can match a particular technology with a particular application, they often cannot distinguish between the dozens of available products—both hardware and software—that would best suit their needs. As a result, many companies have to rely primarily on vendors for information. But while these sources usually have a good understanding of the particular product they are marketing, they do not necessarily know how best to integrate it into a company's manufacturing system.

Reality is sometimes hard to accept, so people spend more time diverting themselves with wishful thinking than taking effective action. In a number of cases we observed, management honestly believed that it was at the cutting edge, despite much evidence to the contrary. At the extreme, some firms regarded the use of a single computer—even a 64K micro purchased five years ago—as a quantum leap into the age of information technology. Others boasted of a customized piece of "automation" equipment they had thrown together out of spare parts. Some companies believed that manually counting the number of parts in their storeroom twice annually and entering these data into their computer constituted a computerized inventory control system.

When companies make investments in new tools—whether modest or relatively large-scale—without an overall strategy for their use, the well-documented result is "islands of automation." Sophisticated technologies acquired at random sit scattered on shop floors, contributing only a fraction of their potential worth toward manufacturing a better product. In one company we visited, a $90,000 robot sat idle for most of two years because the equipment it was supposed to load was 25 years old and kept breaking down.

Of the industries examined, the most serious deficiency in the use of technology was shown by the machine tool companies. This is especially ironic, since the machine tool industry actually makes much of the equipment that could render it more competitive. Despite the deep inroads made by foreign competitors into American manufacturers' markets, many of the companies visited did not appear to appreciate the vast changes taking place in their industry.

One machine tool company told of having a computer for three years, but getting rid of it because the managers didn't know what to do with it. Some companies indicated that they were still in a down cycle for the industry and, apparently oblivious to Japanese imports, expressed the view that things would return to normal as soon as the cycle turned upward. One of these companies observed that it had not made a major sale in two years to the automobile industry—historically its largest market—because of the "recession," even as GM, Ford, and Chrysler were announcing record profits.

These firms generally felt that foreign competition had managed to penetrate their markets more because of cheap labor, government subsidies, and the high value of the dollar than because of any failure on the part of U.S. industry to remain competitive. Such external factors are certainly not negligible, but placing the blame on them alone has become a convenient excuse for not modernizing faster.

Managers will have to fundamentally change their attitudes in order for U.S. industry to take advantage of new production technologies. Once and for all, they will simply have to face the music. The complacency often expressed by American manufacturers must give way to the recognition that change is inevitable. The need for new production technologies must be acknowledged, and plans to use them to their fullest potential must be developed and put into action. Where managers are not equal to the task, they should either bone up or get out of the way. □

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Manufacturers must face the music

Jacques Koppel
Director, Technology Management Center
Philadelphia, Pa.

Technologies such as robots, lasers, sensors, machine vision, and computer-aided design have been hailed as the principal means for helping American manufacturers become more competitive
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neers schooled in another era often find them baffling. They have difficulty identifying the type of system that could most benefit their operations. And even if a firm can match a particular technology with a particular application, they often cannot distinguish between the dozens of available products—both hardware and software—that would best suit their needs. As a result, many companies have to rely primarily on vendors for information. But while these sources usually have a good understanding of the particular

for most of two years because the equipment it was supposed to load was 25 years old and kept breaking down.

Of the industries examined, the most serious deficiency in the use of technology was shown by the machine tool companies. This is especially ironic, since the machine tool industry actually makes much of the equipment that could render it more competitive. Despite the deep inroads made by foreign competitors into American manufacturers' markets, many of the companies visited did not appear to

must give way to the recognition that change is inevitable. The need for new production technologies must be acknowledged, and plans to use them to their fullest potential must be developed and put into action. Where managers are not equal to the task, they should either bone up or get out of the way. □

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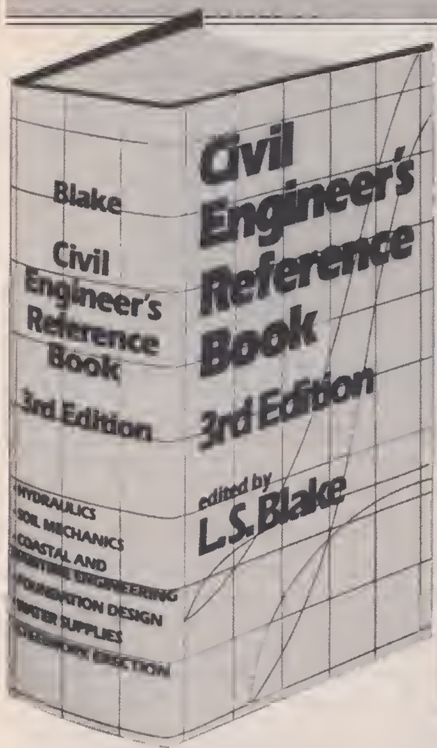

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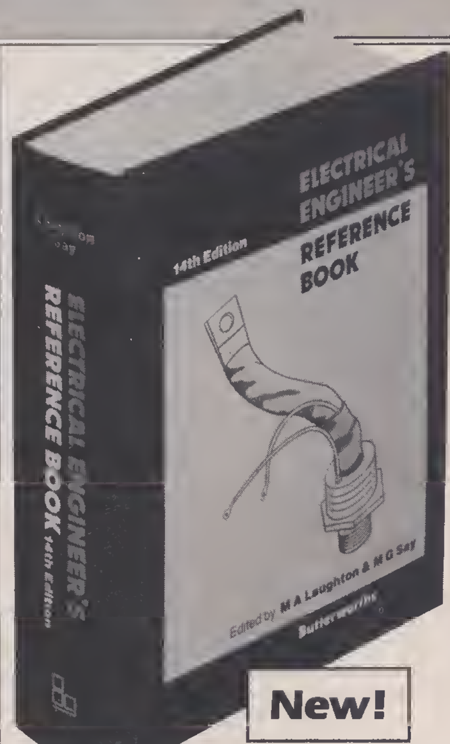

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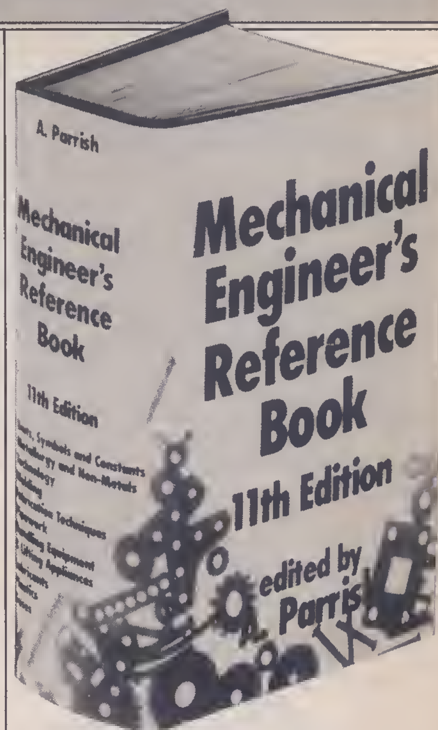

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Norton

PITTING CERAMIC BEARINGS AGAINST STEEL

Japan is considered to have the inside track in advanced ceramics—a diverse industry that in 1985 generated revenues of $5.2 billion worldwide, according to Strategic Analysis, a market research firm in Reading, Pa. But now U.S. companies have also begun to step into the "New Stone Age" of high-performance ceramics. Among them is 100-year-old Norton (Northboro, Mass.). Three years into a program to develop new materials for industrial bearings, the company believes it can snag a hefty share of an estimated $300-million-a-year market for ceramic bearings.

Norton's big gun is its Noralide silicon nitride—a tough ceramic less than half the weight of steel that is able to run at temperatures high enough to turn conventional steel bearings into molten puddles. Moreover, the material's relatively low coefficient of friction means that, in some instances, it can be used even without lubrication. "This is going to be one of our most important new businesses," predicts James G. Hannoosh, director of new business development for Norton. He adds that Norton is already selling ceramics to every major bearing company in the world, including many firms in Japan.

The move into advanced ceramics by a company often regarded as one of New England's "gray ladies" isn't as radical as it first appears. Norton has long been a leader in the related field of heat-resistant refractories and industrial abrasives, which accounted for 54% of its $1.2 billion in 1984 sales. The company is not only a major producer of silicon nitride, but is also working with other ceramics such as silicon carbide and zirconia to derive proprietary ceramic compositions.

But why emphasize bearings, a particularly tough test for a new material? Credibility, says James R. Walker, business manager of the high-performance ceramics group: "High-speed bearings could receive 10 times more stress than any other machine component." Success in bearings could be a

Norton's James Hannoosh, shown with a "sphericity measurement" machine, which the company uses to gauge the roundness of its ceramic ball bearings.

tour de force for the company's materials and open up many other kinds of new business. Thus, Norton's strategy isn't to become a bearing manufacturer, but to supply parts—either finished balls or semi-finished rollers and rings (the "carriages" in which the rolling elements actually roll) for finishing and/or assembly elsewhere.

Although new alternatives won't be an easy sell to cautious bearing suppliers, there are promising signs. The aircraft industry has already begun studying silicon nitride and other high-performance ceramics for use in airplanes, including Navy jet fighters. "Some of these programs show that the ceramic bearing lasts several times longer than steel," says Walker. Silicon nitride can operate at temperatures as high as 2200° F, compared with 600° F for competitive steel bearings. And unlike more brittle ceramics, which tend to shatter without warning, silicon nitride first develops pits—just as steel does—causing obvious symptoms due to the increased heat and abrasion to surrounding components. "If this bearing is in a helicopter, you'll still get home safely," says Walker, "which might not be true for a bearing that fails suddenly."

Silicon nitride appears to be a natural choice for high-speed equipment such as aircraft engines and turbochargers, as well as for auto and truck engine parts, including pistons and cylinder sleeves. The ceramic is only about 40% as dense as many steels, so it reduces the dynamic loading and thus creates less internal stress, explains Tedric A. Harris, VP of product engineering and quality at SKF Industries (King of Prussia, Pa.), a major bearing maker. And the chemical inertness and corrosion resistance of silicon nitride and other advanced ceramics makes them excellent candidates for applications such as nuclear reactors and food-processing plants.

Still, no one believes that ceramics will totally displace steel bearings. "These materials change a lot of the design requirements," says Harris. "For example, they have different thermal expansion characteristics

than steel; that could be a problem in hybrids" (bearings in which ceramic rolling elements are fitted into steel rings).

Also, silicon nitride bearings are still quite expensive. "Say this costs $15," says Hannoosh, holding up a gleaming black silicon nitride ball. "A steel bearing of the same size and for the same application costs about $2. But a few years ago, the ceramic ball cost about $100. As production increases, the price difference will keep shrinking."

Most limiting of all, perhaps, is the conservative nature of the bearing industry. Companies don't talk much about new designs and materials; those already working with ceramics tend to keep quiet until a wealth of performance data have been gathered. "We're constantly aware of the safety factor in many applications, such as aircraft engines," says SKF's Harris. "That makes ours a very cautious business." ***—H. Garrett DeYoung***

Schwartz Electro-Optics:

FROM SIMULATED BULLETS TO STAR WARS

When the Secret Service acts out mock attempts on the president's life or when the FBI and police departments stage gun battles to train new recruits, they no longer have to risk injury from the occasional misfiring of blank ammunition. Increasingly, law enforcement organizations—as well as the military—are using laser-based weapons simulators in their training exercises. And, as likely as not, the simulators are made by two-year-old Schwartz Electro-Optics (SEO—Orlando, Fla.). One of just three companies nationwide that supply a U.S. market estimated by Defense Marketing Services (Greenwich, Conn.) at $94 million in 1984 and $143 million in 1985, SEO is also trying to adapt laser technology to other areas, such as the government's Strategic Defense Initiative, better known as Star Wars.

SEO's Lasertrain simulators, which can be customized to fit revolvers, automatics, rifles, shotguns, and submachine guns, emit a harmless beam of light that approximates the trajectory of ordinary ammunition. The pull of a trigger activates a shock sensor in the system, which sends a signal to a junction-diode laser powered by a nine-volt battery (good for up to a million rounds). The laser releases light through a lens, creating a half-inch beam that widens to an inch at 20 feet.

The company also sells what resembles a bulletproof vest but is, in fact, a laser beam–activated target. Fiber optic threads sewn every half inch detect direct hits and activate two chest-level devices that start beeping and flashing. The beepers can't be turned off without a special key—to eliminate cheating. Systems consisting of a laser-based weapon and one target, which can be a bull's-eye or a human silhouette instead of a vest, are priced from $1700 to $3400.

"The systems give us the ability to increase the realism in all sorts of training," says Detective Scott A. Cunningham, of the training bureau of the Tampa, Fla., Police Department, one of SEO's first customers. The department uses simulators for marksmanship training as well as for mock crime enactments. "Using live ammunition would eat up too many recruits," he says, and even blanks can cause injury.

For William C. Schwartz, SEO's 58-year-old founder and president, the start-up is only the latest in a long series of laser projects. After managing Martin Marietta's laser programs, he founded International Laser Systems—now a subsidiary of Litton Industries—where he first developed the weapons-simulator technology that SEO subsequently purchased. Schwartz started SEO in October 1983 with $1.5 million from private investors, and the company landed its first contract eight months later. It reported revenues of nearly $2 million in 1985 and expects sales to double this year.

In contrast to many other markets for laser-based equipment, weapons simulation is "a technology you can get into with a relatively modest capital investment," says Schwartz, and it is still a field with "a limited number of competitors." The firm's customers include the Secret Service, the FBI, the Federal Law Enforcement Training Center, the Department of Energy's

SEO's William Schwartz holds a revolver modified to shoot harmless laser beams at a light-sensitive vest.

nuclear reactor security force, and a handful of Florida police departments.

Already eyeing new markets, SEO also has several R&D contracts and grants in other areas. The company's Boston-based research branch, headed by Peter F. Moulton, formerly of MIT's Lincoln Laboratory, is working on "tunable" crystal lasers that can operate at several frequencies, in contrast to most lasers, which produce light of only one wavelength. Currently, the only tunable lasers use liquid dyes, many of which are corrosive, toxic, or unstable.

And like scores of other companies engaged in laser research, SEO hopes to snare a contract for development of laser systems proposed for the Strategic Defense Initiative. With R&D projects already under way at SEO to adapt lasers to airborne or shipboard position-location systems, the small maker of bulletless training weapons may well be in the running for bigger game.—***Elizabeth Willson***

Dest:

PCs LEARN TO READ

With their ability to perform fast calculations and keep untold numbers of facts in order, personal computers have become indispensable in more than a few offices. But until recently, PCs couldn't do one of the most rudimentary business tasks: read a printed page.

True, machines called optical character readers (OCRs), which can decipher the shapes of letters and translate them into computer code, have existed for some time. But early versions cost far more than an average PC's entire purchase price. These models would have to be scaled down considerably to attract budget-minded PC owners.

That is essentially the strategy of Dest (Milpitas, Cal.), a leading manufacturer of OCRs in the $6000–$10,000 price range designed for use with minicomputer-based office-automation equipment. Now, for $2590, the company is selling PC Scan—a new, compact page scanner—and the software that enables it to translate typed text into coded formats utilized by several of the most popular personal computer word-processing programs.

Dest, which logged $20 million in revenues in the year ended March 1985, hopes to make up in sales volume what it will undoubtedly spend to enter the retail-oriented personal computer market. "We don't have much name recognition in the PC market," acknowledges VP of marketing Lee Cannon, and thus the firm will need to "advertise heavily."

To operate PC Scan, users simply feed in pages one at a time; the briefcase-size machine scans an average page in 5 seconds and formats it in another 25 seconds. However, it can currently read only certain kinds of type, concedes Cannon. It is limited to 12 type styles produced by typewriters or letter-quality computer printers. It can't read dot-matrix printer output, typeset text, or speckled photocopies.

This limitation is just a "small weakness," says Shelley Bakst, an analyst for market research firm International Data Corp. (IDC—Framingham, Mass.). More serious, she maintains, is PC Scan's inability to decipher images such as charts and graphs. "Users want both OCR and image-processing technology," asserts Bakst, preferably integrated into a single device.

Such integrated systems will eventually become the norm in all segments of the OCR market, squeezing out simpler, text-only processors, predicts Naomi Kalmus, an analyst for International Resource Development (New Canaan, Conn.). "The OCR-only market will peak in 1987," she says. Aware of the trend, Dest claims it will introduce text-and-image integration for PC Scan before long. In fact, the company designed the machine to scan at a finer resolution than its predecessor for just this purpose, says the firm's president, Richard Amen.

Whether or not PC Scan is further refined, it currently has almost no competition in its price range, although several companies, including Datacopy, Data Systems, and Compuscan, make similar but higher-priced systems. "The real competition will come from Japanese companies like Canon, Fujitsu, and Ricoh," contends IDC's Bakst. "These companies have always been good at imaging technology," she says, and are no more than a year away from adding text-reading capability. —***Sarah Glazer***

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MICROS GET GRAPHIC

New systems offer unprecedented versatility and ease of use, but the lack of standards holds back the revolution

◆ by Cary Lu ◆

For microcomputers and their printers, coping with graphics has always been a struggle. Early micros largely ignored graphics and followed a typewriter model—they could display only text, which appeared in a single typeface and size with fixed, typewriter-style spacing. Such text-based computing has dominated micros and mainframes alike because the hardware and software are relatively easy to design.

Yet for the past 15 years researchers have been developing computers specifically to work with quality graphic images. These computers did not simply create images on screen but also addressed the fundamental issues of user/computer interaction. Work at Stanford Research Institute and Xerox's Palo Alto Research Center led to the experimental Alto and then the landmark Xerox Star, the first commercial computer with full-time graphics and a modern user interface. Although the Star was too expensive for wide distribution, its ability to manipulate graphics as easily as text, and to display text complete with different typefaces and sizes, made a deep impression on the microcomputer industry.

The second graphics computer, the Apple Lisa, brought the price down to $10,000, but that was still too high. Apple had to make one more effort, resulting in the Macintosh, before graphics-based microcomputing could be practical for a large market.

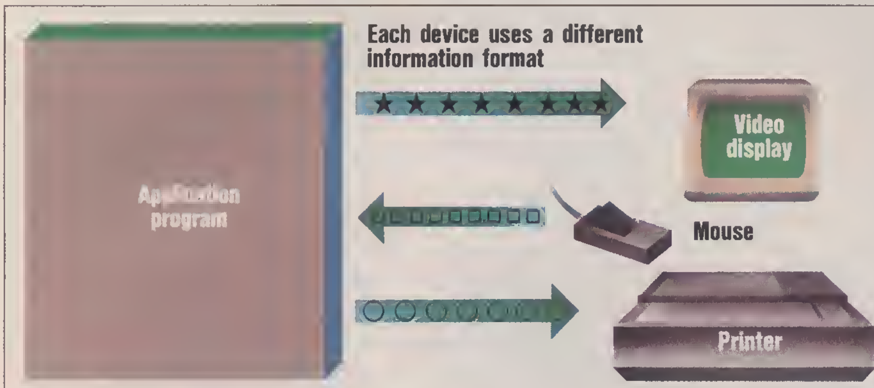
The advantages of graphics-based computing are so compelling that all new microcomputers, including the new Atari ST and Commodore Amiga now work in this fashion—as do the most important developments for the IBM PC series. The IBM PC, in its common monochrome screen form, is probably the last important text-based microcomputer. The obsolescent PC and PC/ XT can run the new graphics software, but not nearly as well as the newer PC/AT and its clones.

When a text-based machine generates a character on the screen, the software merely sends a simple character code to the video controller. The controller hardware creates the screen display from the code by looking up the matching bit image (bit map) for the character in ROM (read-only memory) and modulates the electron beam in the CRT accordingly. When the time comes to print, the software sends the character codes to the printer, which uses its own bit maps or daisywheel spokes to create the same limited choices on paper. The actual shape of the printed character is completely independent of the computer's display.

With graphics-based computers, the screen is always driven as a graphics device, even for ordinary text. This places a considerable burden on the software and hardware, which now must cope not only with a simple character code but also with the typeface, size, and style (bold, italics, outlined, and so on). The screen driver must calculate every pixel of every character each time it writes on the screen. This added burden has inhibited graphics-based software in the past. (Many earlier micros did, of course, have some graphics capabilities. They generally operated in two distinct modes—either text or graphics, but usually not both at the same time, and the very-low-resolution graphics were coarse and unappealing.)

To manage the graphics and the text variations, the Macintosh has a built-in software package in ROM called QuickDraw. All Macintosh programs send instructions to QuickDraw, which converts them into screen images. Because all programs employ this common set of instructions, they can easily share pictures and text. Written by Apple Fellow Bill Atkinson, QuickDraw is now the most widely used graphics format, even though it is found only in the Macintosh (and the discontinued Lisa).

IBM, on the other hand, makes no particular provision for graphics. Because the IBM PCs have neither ROM routines equivalent to the Macintosh's nor any standardized way to specify graphics, every program performs even the simplest operations differently. The Lotus 1-2-3 graph format has become a kind of de facto standard, but it can specify only a few simple business charts. (A small industry has arisen to provide software for polishing up 1-2-3 graphs; the program that produces the



Traditional graphics application programs handle all input and output devices directly. Each program has to incorporate the specific steps necessary to accept information from an input device such as a mouse and send information to an output device such as a video display or a printer. The different arrow patterns indicate the varying information formats required by each device. In most cases, graphics information cannot be passed on to a second program.

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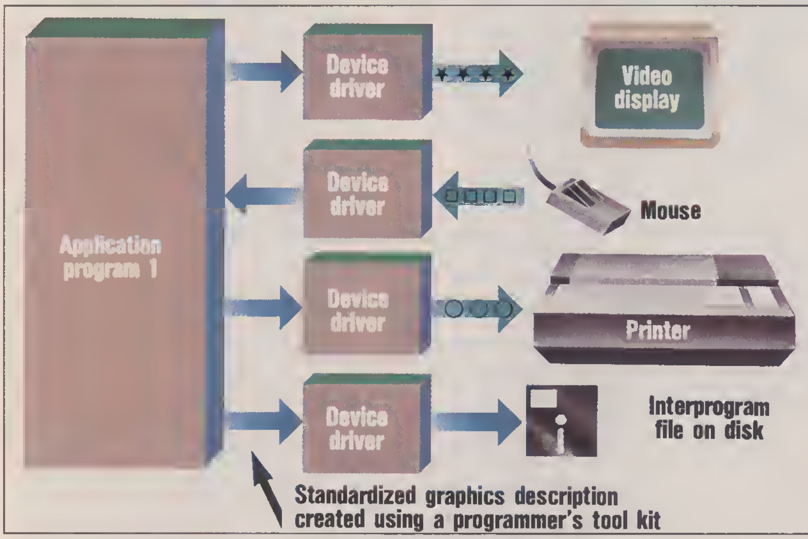


The newer application programs work with a universal standardized graphics description rather than multiple formats. The uniform arrow patterns show where the information flow follows the standard format. Device drivers translate from the standard to the specific formats needed by each device, so the application program need no longer be concerned about specific devices. Graphics information can also be stored on disk or in RAM and passed on to a second graphics program.

MICHAEL BLASER

cleanest presentation graphics is Grafix Partner from Brightbill-Roberts.)

The challenge for the micro industry is to establish and support a graphics standard—a uniform way to specify pictures and text. Not only would this help to achieve device independence and software-file compatibility, but it would offer the opportunity to standardize the user interface as well.

Device independence means that the application developer no longer has to build or write drivers—which create, either in hardware or in software, the necessary display commands—for every device under the sun. With a universal graphics description, each device

Graphics standards promise a largely standardized interface, so skills learned with one program will be transferable to others.

would need only one driver. Thus a company planning to introduce a novel device would need to write only a single software driver and would not have to go around trying to convince software developers to support it.

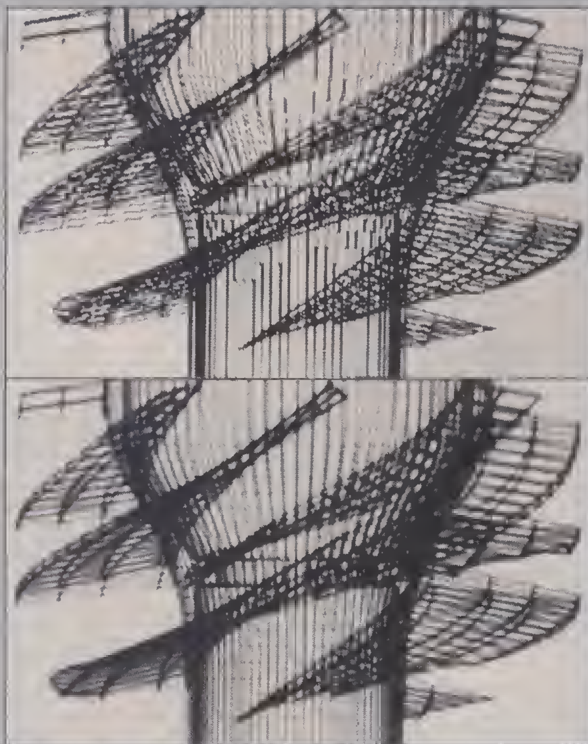
Similarly, the standardized graphics description will allow one software application to store an image on disk or in a portion of RAM and pass it on to a second application. Neither one will need to "know" what the other does; with a common file format every program will understand whatever information it is capable of dealing with.

Programs based on a graphics standard also promise to bring with them a largely standardized interface, so that skills learned with one program will be transferable to other programs. No longer will users have to consult a lengthy manual just to figure out such simple

◆ Display complications ◆

Graphics poses special problems for low-resolution display devices. Such devices—mainly CRTs—work best when the image is carefully planned to take into account the low pixel count. Text is a big problem; in the smaller type sizes, a CRT may not have enough pixels to distinguish one typeface from another. A partial solution has been generic fonts, usually one with serifs and one without; you can see the actual font only on the printed output. Careful screen font design, such as that done by Adobe for PostScript fonts on the Macintosh, can usually solve this problem. The smallest characters present additional problems because they aren't legible on the screen, even though a laser printer will produce them clearly. A simple solution would be to incorporate a magnification mode into the software.

Another problem with CRT images is the pixel's aspect ratio—its height relative to its width—which many hardware designers have not thought about carefully. The best and most flexible display uses square pixels, where the screen has the same resolution vertically and horizontally. With square pixels, rotations and sideways text can be displayed easily without distortion. With rectangular pixels, the programmer must decide whether to preserve pixel correspondence or shape correspondence. Pixel correspondence ignores the aspect ratio and simply maintains one-to-one mapping for pixels. This causes geometric distortion during operations such as rotation. Shape correspondence maintains the overall proportions but often introduces artifacts, since objects will have to be stretched or compressed. Such adjustments can rarely be made smoothly.



Low-resolution displays such as a video screen produce "jaggies," or aliasing, along edges (top). Anti-aliasing smoothes the jagged edges by adding gray pixels.

ADOBE

The Macintosh is the only common computer with square pixels (although the Apple Imagewriter printer's pixels aren't quite square). On the IBM PC, none of the common display adapters has square pixels, a considerable nuisance. You can open up a monitor and adjust the vertical and horizontal size controls to create square pixels, but then programs that correct for the nonsquare aspect ratio don't look right. To deal with these problems, a flexible standard offers the programmer a choice of pixel or shape correspondence and other ways to fit images within a particular output device.

Aspect ratio problems mainly concern low-resolution devices. Medium (250–500-dpi) to high-resolution (over 500-dpi) devices—page printers and typesetters—have enough pixels to produce a decent rotated image even if their horizontal and vertical resolutions do not match.

The increasing use of graphics is showing up the severe limitations of some CRT displays. The most common very-low-resolution displays—such as the IBM Color Graphics Adapter and the Commodore Amiga displays in their 200-line form, with only 30 dpi vertically—are unsatisfactory for most business applications, but they have two advantages: Even a cheap monitor can handle the signal, and their video images are relatively easy to combine with broadcast television images.

Display quality is restricted by cost; the best displays currently practical for micros have only about 100 dpi, and even at this resolution the low-cost displays have relatively poor contrast. Improvements in electron beam control should lead to 150-dpi black-and-white displays within a few years—an important advance, particularly if incorporated in a full-page size (60 lines of 12-point text in a vertical screen).

At the resolutions available now and in the near future, all displays suffer from aliasing, or "jaggies," in an image. Look at any straight line that is not vertical, horizontal, or at a 45° diagonal; you will see a jagged, stair-stepped line. The most practical anti-aliasing technique adds gray pixels next to the rough edges, producing the illusion of a smoother image. Even though this gray-scale method calls for a larger video RAM (since gray information must be stored for each pixel), it is effective and relatively inexpensive. Unfortunately, anti-aliasing requires more computation, so it slows everything down unless performed by a separate graphics processor. The more levels of gray the better; in the future, some displays might use an essentially analog video image with a continuous tonal range like television rather than today's all-or-none digital images.

Color displays are a special problem, since they depend on a triad of color phosphors and a tightly controlled electron beam. With ideal registration and perfect beam control, only a smudged 70–80-dpi color image is possible today at reasonable prices; the image is much less clear than on the better monochrome displays.

Aside from the technical problems, color also raises many practical questions. Although visually attractive, color images are hard to print. The most efficient color printers employ ink-jet or thermal transfer technology and cannot match the clarity of a daisywheel or laser printer. Color laser printers are in the offing but will be expensive and probably difficult to maintain. Besides, photocopies are the most common distribution medium today, and few offices have color copiers.

The human eye creates one further problem with sharply etched, brilliantly colored graphics. Since the eye lacks color correction, strongly contrasting colors produce slightly mismatched images on the retina. The colors therefore appear to be located at different depths in space, resulting in a "color stereo" effect that contributes to visual fatigue. Overall, given a choice of either color or twice the resolution in monochrome, the latter seems more promising.

steps as opening and closing a file or editing an entry, and the confusion that even an expert often experiences when learning a new program or relearning a long-unused one will largely disappear. From the user's standpoint, such a standardized interface may be more important than graphics standards per se.

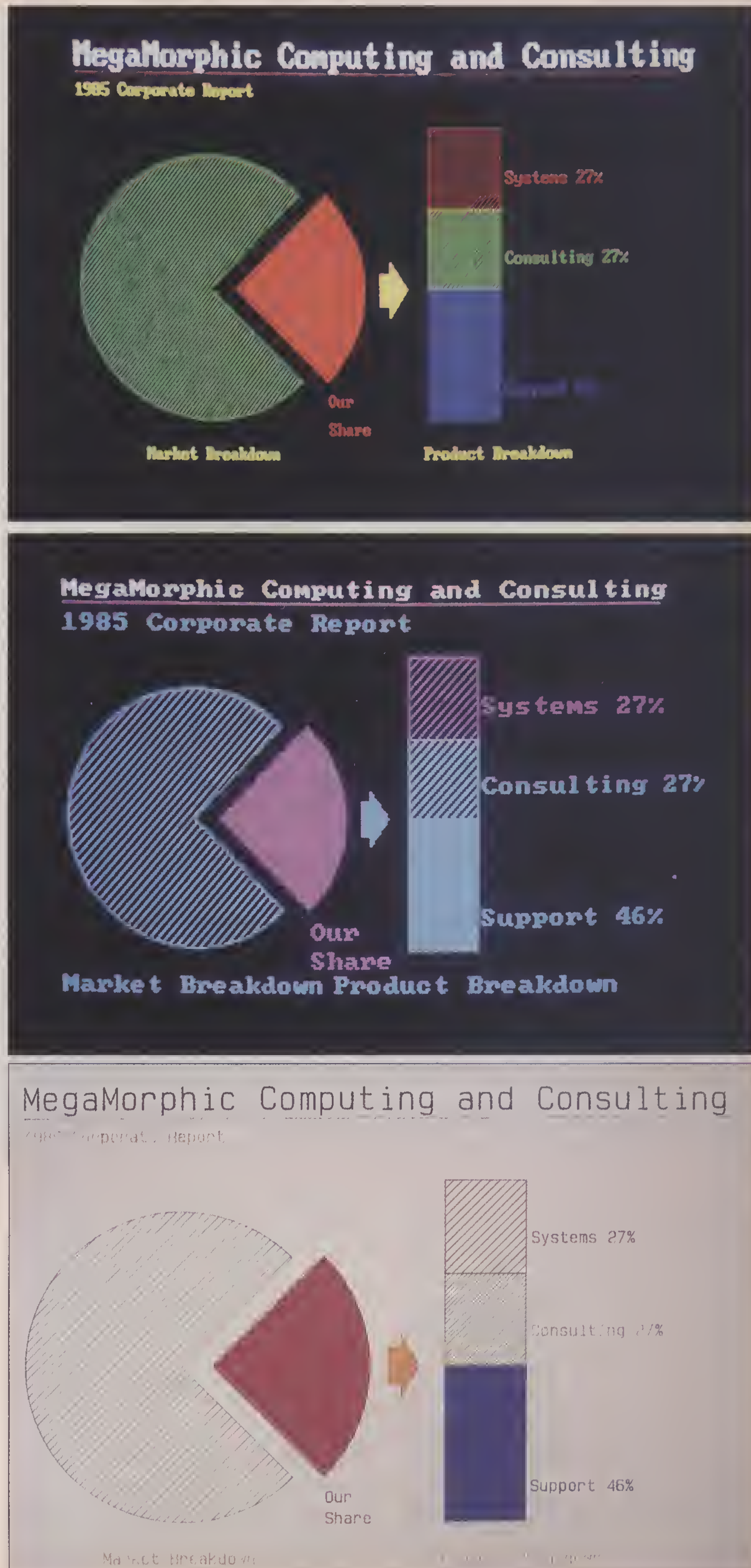
Three companies—Digital Research, Microsoft, and Graphic Software Systems—are vying to establish graphics standards. All three began developing standards using variations on the Virtual Device Interface (VDI), a graphics description format that has been under development by several companies for about five years, mainly on small computers. Despite its passage through standards committees, VDI exists in several incompatible variations.

Digital Research and Microsoft began with VDI as it existed two years ago and adapted it for their products. Digital Research's GEM and Microsoft's Windows are "operating environments" that perform in software what the Macintosh does in firmware (ROM) and hardware. Because they are, in effect, pasted on top of a hardware design that was not optimized for graphics, neither these nor other mouse-driven graphics systems for the IBM PC work quite as crisply as the Macintosh. Yet both GEM and Windows are more than serviceable; they both work well and are a tremendous improvement on raw MS-DOS and typical IBM PC software. A version of GEM also controls graphics on the Atari ST.

Graphics-based computing is so compelling that all new microcomputers work in this fashion.

Graphic Software Systems has stayed close to the formal decisions of the standards committees, and now offers its version of the Computer Graphics Interface (CGI), which is the March 1985 ANSI (American National Standards Institute) incarnation of VDI.

The Graphic Software Systems entry that implements ANSI CGI, called GSS/CGI, deals only with device independence and software compatibility. Although it includes the tools to create a



PHOTOS BY GSS

A graphics description is interpreted by device drivers to render the image with the capabilities of a particular output device. In this comparison, the same graphics description generates images on two video displays (top and center) and on a color plotter (bottom).

◆ Graphics printers ◆

Because impact dot matrix printers print individual dots independently ("all points addressable"), most of them can produce bit-mapped graphics. But virtually all such printers leave it entirely up to the controlling software to create objects. The printers themselves cannot create a line from the coordinates of two end points, so the controlling software must generate the line by specifying all the necessary dots. Thus these printers all need driver software that can create a complete raster, or lines of dots that are turned on or off. The specific description of the raster varies with the printer model; if your printer uses an obscure description, you will have trouble getting it to work with some graphics-based software, however desirable its other specifications may be.

The most popular raster description was developed by Epson for its MX and FX printers (as well as the original IBM Graphics printer, which was made by Epson). Many printers now claim to use the Epson raster description, but many fall short of exact emulation; check all compatibility claims carefully.

Software drivers for traditional dot matrix printers have been fairly easy to write, in part because the printers operate slowly—typically at a few hundred to a few thousand dots per second—and can pause in midpage for more information. The printer needs only a modest memory buffer, one large enough to accept the information needed to print a small band on the paper; the printer pauses after each band to receive information for the next band.

New page printers, which use lasers or LED arrays, cannot pause during operation. The printing is so fast (a million dots or more per second) that standard data transmission techniques are too slow for the computer to transfer the raster to the printer during printing. As a result, a page printer must usually have a full page buffered in memory before it starts printing. At 300-dpi, an ordinary page occupies about a megabyte. Cheaper page printers—those priced below $4000, like the Hewlett-Packard models—don't have a megabyte and so lack full-resolution graphics. Instead, full-page graphics comes out at the same resolution as an impact dot matrix printer, 75 or 150 dpi. The printed page looks better, however, since laser printers produce a cleaner image with higher contrast and more tightly defined dots than their mechanical cousins.

The cheapest full-graphics page printers use a megabyte memory for the page image but lack the ability to process graphics descriptions, relying instead on driver software to create the raster. This places considerable demands on the driving software; the computer's main CPU must calculate every bit in the image, a process that can make for painfully slow printing. And these simple printers will have difficulty working effectively with the new graphics standards.

Sophisticated laser printers include a megabyte of page buffer memory and an internal processor that can create the raster from graphics descriptions. These descriptions reduce the amount of information passed between computer and printer, speeding up printing; to draw a line, the software merely sends the end points, orientation, and thickness. All such printers can also accept bit map information directly from the computer, but because transferring a bit map takes so long, they do so only as a last resort for complex images.

The new IBM and NEC page printers use LED imaging technology. IBM's printer works at only 240 dpi and produces distinctly poorer quality than the competition; it is really designed for use with IBM's minicomputers. For competitive reasons, IBM will probably have to introduce a better page printer soon. NEC has 300-dpi but a somewhat larger dot size (about 6 mils) than most laser printers (about 4 mils). Both IBM and NEC are positioning their printers as daisywheel replacements, since they feature typefaces modeled after typewriters rather than typesetters. Whether software developers will support these two incompatible graphics description formats remains to be seen.

The most sophisticated page printers available now for microcomputers incorporate a PostScript processor. These units include Apple's LaserWriter (with a Canon LBP-CX printing engine), three units from QMS (with Canon and Xerox engines), and Dataproducts (with a Toshiba engine).

All laser printers still fall far short of typeset quality. The printed image is rough because the toner is squashed as it is pressed to the paper during the fusing process, turning pixels into irregular shapes. Stray bits of toner mar the white areas, and the blacks are uneven because toner particles repel each other on the photoconductor drum. Although some laser printers boast 800 dpi or more, their output suffers from the same problems—and the dots overlap rather than butt up to one another, because the dot size is only a little smaller than on the 300-dpi models. The additional resolution helps mainly in creating smooth curves.

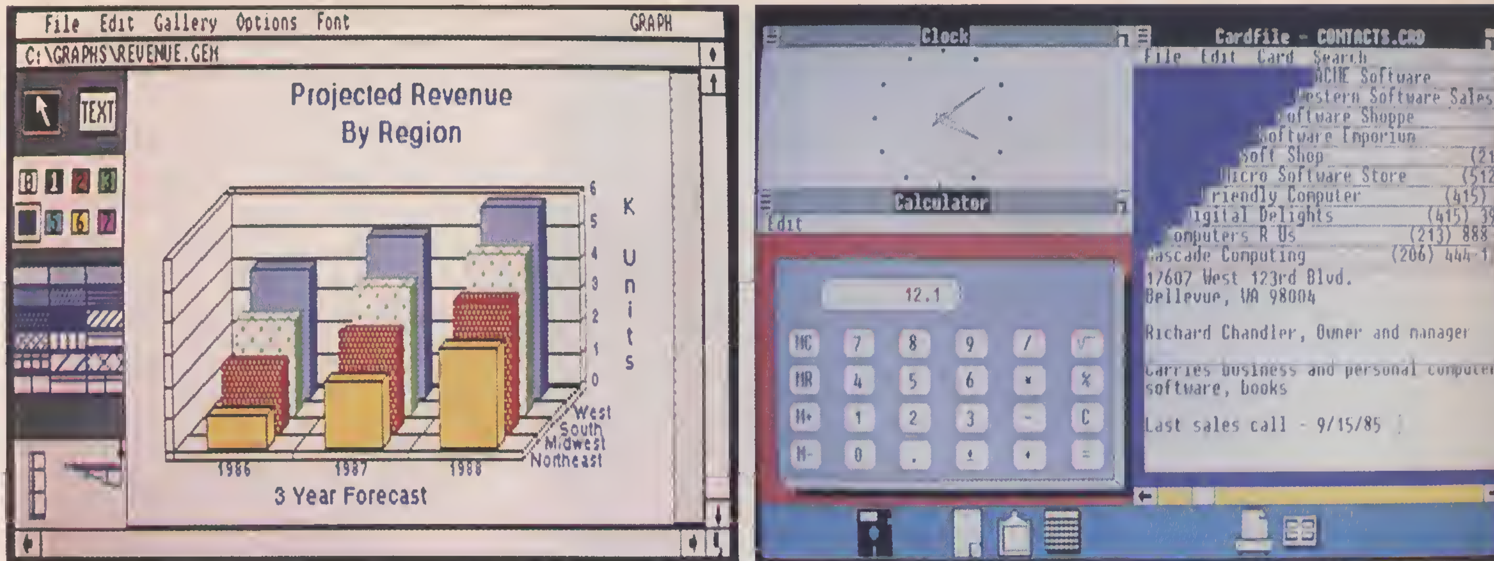
Only typesetters yield true typeset quality. The first ones designed to work with micro graphics standards are the Allied Linotron 101 ($30,000) and 300 ($57,000), with maximum resolution of 1270 dpi and 2540 dpi, respectively, and dot size under 2 mils. Aside from the resolution, the output has absolutely clean whites and smooth blacks.

user interface, it does not explicitly create any particular interface; the company argues that this gives the software developer more freedom. Separate from the interface issue, the device-independent driver side of GSS/CGI may play an important role; for one thing, both GEM and Windows can use these drivers. And GSS/CGI is available for a variety of computers, such as the AT&T Unix PC. If enough Unix software supports it, CGI could give the Unix operating system a graphics standard, if not an interface standard.

From the user's point of view, the key question is which standard—GEM, Windows, or GSS/CGI—will gain the widest support. All three are at embryonic stages, with only a handful of supporting products thus far. You can buy GEM and Windows as a package with a painting and word-processing program and then add further compatible software. Although both GEM and Windows will work with many existing text-based programs, both shine only with specially designed software that embraces their operational style. To adopt GSS/ CGI, you do not buy a specific product; you just look for programs that are compatible with that standard.

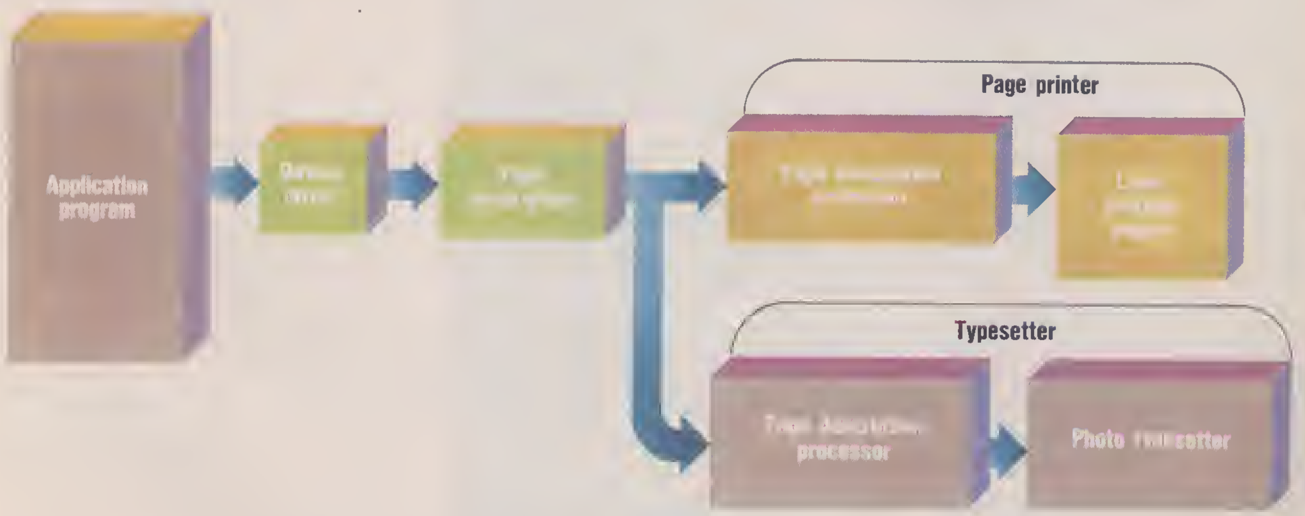
The most visible competition thus far is between GEM and Windows. Despite a later start, Windows has better software in two important areas. Windows Write, although not a full-featured word processor, is far more capable than GEM Write; and Micrographix's In-a-Vision under Windows is better for structured drawing than GEM Draw. There are, nevertheless, some promising developments in forthcoming GEM applications, particularly Ventura Software's page makeup program.

From the software developer's point of view, choosing one of these standards means getting a software tool kit, a special set of modules that add standardized graphics capabilities to existing computer languages. Programmers no longer have to write the codes that create and manage text and graphics. Instead, they call up the tool kit, and it does the detailed work.



PHOTOS BY DIGITAL RESEARCH

Along with a graphics standard, the GEM (left) and Windows (right) operating environments also incorporate a user interface standard. The environments manage the windowing and menus as well as the on-screen graphics.



A page description language is a specialized graphics format optimized for the printed page; the specifications meet typesetting requirements. A device driver converts graphics information from the application program into the page description language, which can then drive a laser printer or a typesetter without further modification. (Earlier microcomputer products designed for typesetting generally required extensive modifications for each kind of output device.)

MICHAEL BLASER

At the most fundamental level, nearly all graphics devices, whether screens or printers, operate with bit-mapped images. Each pixel in a bit-mapped screen corresponds to (is mapped to) a bit in RAM. To change the screen image, the software changes this video RAM as required. Graphics printers work in the same fashion, except that the bit map need not be held in RAM all at once. Instead, a typical dot matrix printer works slowly enough that the bit map is built up in RAM gradually, one band of the image at a time. The faster page printers, using laser or LED imaging, generally need to have a complete page in memory when printing starts.

No single graphics standard is likely to displace all others, so a new market will develop for translators.

Purely bit-mapped graphics works fine when the image will appear on a single display device at a fixed resolution. But in the typical case, where the screen uses one resolution and the printer another, bit mapping does not work well. The bit map that can create a satisfactory screen image at 60–100 dots per inch (dpi) will not produce an acceptable image on a printer at 140 dpi, and is hopelessly inadequate for a laser printer at 300 dpi; there simply isn't enough information to fill in the additional pixels. Although an interpolation and smoothing scheme can sometimes build up an adequate image from a lower-resolution original, no such scheme works well enough to be generally useful.

The alternative to pure bit mapping is to describe images with graphics primitives, which specify geometric objects; a line, for example, is defined by its length, orientation, and width. A full

graphics-primitive language includes enough components to specify virtually any object; the more complex the object, the greater the number of graphics primitives necessary to describe it. From the complete graphics description, a driver (software or hardware or both) can create a bit map for a particular screen or printer, taking full advantage of the device's features to render the image at the best possible resolution, and using color if available and shades of gray if not.

Thus, on a screen with only 60 dpi, a graphics primitive for a circle will yield a rough-looking curve. The user can manipulate the jagged circle, secure in the knowledge that when the time comes to put it on paper, the driver for a laser printer will take the same primitive and create a smoothly executed 300-dpi circle. In a way, graphics primitives do for graphics what the ASCII character code does for text.

Graphics primitives alone, though, are not always sufficient. For example, if you describe a square with graphics primitives, you will define four separate lines. A program that looks at the graphics primitives will recreate the square but has no way of "knowing" that the four lines are actually a single entity that should be operated on together. But a "higher-level graphics" format can group the primitives to create complete objects.

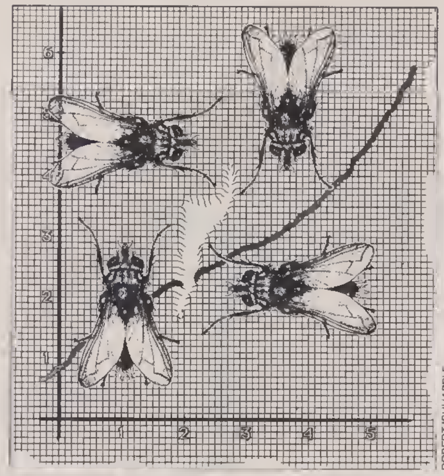
Because programs are designed for so many different purposes, standardizing higher-level graphics descriptions is not easy. Nevertheless, some standards have been proposed or established in specific application areas, such as IGES (Initial Graphics Exchange Specification) and PHIGS (Programmer's Hierarchical Interactive Graphics Standard) in computer-aided design, which run mainly on engineering workstations rather than microcomputers. The most popular higher-level graphics descriptions on micros have been established by the success of specific software packages, such as AutoCAD.

However flexible, no set of primitives can create every possible image. Some images, such as a photograph of a real scene, do not decompose into graphics primitives readily. Such images are best handled as bit maps, so any comprehensive graphics standard must also allow for this method as well. (The addition of raster images is what distinguishes the March 1985 CGI standard from the earlier vector-oriented VDI.) The resolution and other characteristics of the bit map depend on its origin and ultimate use; the main sources will be television images, facsimile machines, and scanners. In some cases, software can analyze a bit map image and create a graphics primitive description. At present this capability is largely limited to converting cleanly made line drawings into line primitives.

STREET SCENE

JERRY CLEMENT

CARTESIAN FLIES



ROBERT TISHI/APPLE

CROW

PAT PERRIN/APPLE

Images created by Bill Atkinson's MacPaint program show a wide range of styles. They can be combined with other types of images and text using QuickDraw commands.

In a comprehensive system, the bit map can have any resolution. The system always stores the full resolution, and the software recreates the image to the extent possible on a particular output device. In putting up such a bit map on screen, the software will offer the user several choices. The image can be displayed at the size it will print—in which case the screen must show a much coarser image—or the screen image can be blown up so there is pixel-to-pixel correspondence with the printer. In the latter mode, a 300-dpi bit map for the printer would appear four times the size on a 75-dpi screen. For features such as gray scale and color, the software must have algorithms for choosing how to display each attribute on devices that do not have grays or color.

Once a graphics description is created, one program can send it to another program instead of to an output device. This can be done via a disk file or a block of RAM set aside by the operating system. Within VDI and CGI, these interprogram files are called metafiles. Within the Macintosh, Windows, or GEM, they are called the clipboard or scrapbook. To move information, you merely delete or copy it from the first program, then switch to the second program and paste it in. Disk files can be used when you want to move or save several pieces of information. Of course, this transfer system works only if the receiving program can understand the information; you cannot paste a picture where a program expects some text, but if the program accepts graphics entries you can incorporate little maps into an address book.

For text, as well as pictures, graphics standards allow a close linkage between screen image and printed output. Different typefaces, styles, and sizes are displayed on screen as similarly as possible to the ultimate printed results. The quality of text handling, in fact, is becoming a major distinction among the competing standards. GEM, for example, does not yet handle multiple fonts and sizes effectively. Windows and the Macintosh can handle multiple fonts as a standard function. CGI supplies the tools, but the use of fonts is up to the software developer.

Beyond pure graphics and text, graphics standards also manage the overall image. They handle multiple windows on screen, overlapping objects, and foreground and background colors, process input from mice for cursor control, and so on. Software developers wanting to use any of these features are spared the necessity of repeating work

New computers will increasingly assign a special graphics processor chip to drive the CRT

that the standards suppliers have already done.

But most of the generalized graphics standards, seeking universality, have not included a full set of typesetting features for optimizing the appearance of the printed page; thus the need for "page description languages," which include not only the usual graphics primitives and text information but also such features as half-toning (to render grays), shadowed and outlined characters, and continuous rotation.

The leading page description language, Adobe's PostScript, was designed to drive higher-quality output devices such as laser printers and typesetters, devices that have at least 240-dpi resolution. Since this resolution is far beyond the capabilities of video screens, PostScript is currently used as a printer output format only; it works in conjunction with the other standards. On the Macintosh, a PostScript driver converts QuickDraw commands into PostScript code. Similarly, GEM already includes a PostScript driver, Microsoft plans one for Windows, and other graphics-intensive MS-DOS programs can drive PostScript printers as well as simpler printers.

PostScript has support from Apple and Digital Equipment Corporation and from Allied Linotype in the printing industry. Allied contributes two key items: typesetters that can take PostScript commands—without changes—and turn out reproduction-grade originals for printing, and quality typefaces. Access to these typefaces is a major advantage for PostScript since many laser printer fonts are poorly done.

PostScript follows the conceptual model of Xerox's Interpress, a page description standard that PostScript's developers originally worked on at Xerox. Interpress has received support mainly from companies outside the microcomputer industry.

Peter Bono, director of strategic technology for Graphic Software Systems, serves as chairman of the ANSI committee that has codified the CGI graphics standard.

No single graphics standard is likely to displace all others, so a new market will develop for products that can translate from one standard to another. The success of the translation will depend on the richness of the receiving standard. Any rich language can incorporate all the features of a simpler description—as in converting QuickDraw to PostScript—but the reverse isn't true. Two languages of equal sophistication will be able to exchange most information, but because of differences in specific features, you might have to adjust a translated file. A receiving standard that lacked a primitive for specifying a parabola, for example, would have to approximate the shape with other curves.

Lacking conversion programs, users must often fall back to a bit map. Some present IBM PC graphics software works by capturing the bit map from video RAM. Similarly, you can use a video digitizer to capture an IBM PC screen display as a MacPaint file for the

Standards aid graphics market

While graphics products have always been a strong component of the computer industry, the market research firm Strategic Inc. (Cupertino, Cal.) estimates that only 1.5 million people currently use computer graphics out of the 31 million who could do so. Graphics-interface standards may help fill this gap by cutting software development time and expense, and by assuring consumers that application programs will be compatible with many different input and output devices.

Several variations on one standard, Virtual Device Interface (VDI), have become commercially available for software running on IBM PCs and compatible machines. Microsoft (Bellevue, Wash.) offers Windows, Digital Research (Pacific Grove, Cal.) produces GEM, Graphic Software Systems (GSS—Beaverton, Ore.) offers Computer Graphics Interface, and Nova Graphics International (Austin, Tex.) sells Nova-GKS. Revenues from these products totaled about \$50–100 million in 1985, and should reach at least \$400 million by 1988, according to Lewis Brentano, a hardware systems market analyst at Dataquest (San Jose).

"You won't have to be a computer scientist to use the software that results from graphics standards. That will bring graphics programs to the office desk in unprecedented numbers."

Lewis Brentano
Market Analyst
Dataquest

"Ultimately, the size of the market for graphics-standard software is as large as the graphics market itself," says Clinton Waggoner, senior VP at Nova Graphics. Program developers are already purchasing graphics-software tool kits—which incorporate standards—to write programs for such diverse applications as slide making, seismic plotting, industrial process control, and military command and control. Waggoner explains that "before the availability of standards, a software company had to either adapt a product to each hardware device with which it might be used—monitors, printers, plotters, and the like—or limit the scope of the product to certain devices." But a graphics standard eliminates such interface problems, enabling a software vendor to concentrate on applications.

Beyond application software, another new market is also emerging: Semiconductor manufacturers are embedding standards into specialized graphics processor chips, which improve the processing speed of graphics applications. "Motorola, Hitachi, Intel, NEC, NCR, and Texas Instruments have announced plans to put VDI on a chip," says Peter Bono, director of strategic technology at GSS. "And more manufacturers are expected to join this group in 1986. Within a few years, graphics chips could comprise a market of at least \$100 million."

An initial application for these processors will be in printed circuit boards that give high-performance graphics capabilities to text-based personal computers. These add-on boards, marketed by companies including IBM, Hercules (Berkeley, Cal.), Tecmar (Solon, Ohio), and Persyst (Costa Mesa, Cal.), currently use graphics-controller chips that do not implement VDI standards. Even without standards, the number of boards sold more than doubled between 1984 (250,000 boards) and 1985 (600,000 boards), and most were for the IBM PC, according to Dataquest's Brentano. He adds that "by 1989, most of the 4.2 million boards purchased will include a standards-based graphics chip, which will free software developers from tailoring their products to each board."

Demand for VDI-based software and graphics boards will also be driven by a rapidly growing market for desktop publishing systems, which harness PCs to low-cost laser printers to produce typeset-quality output. The proportion of corporate publishing done on micros is expected to jump from 17% in 1984 to 67% by 1990, according to Charles A. Pesko Associates (Marshfield, Mass.). "With VDI, desktop publishers can produce more elaborate graphics more rapidly, and at less cost," says Bono of GSS.

When used with high-quality output devices such as laser printers and typesetters, VDI products must compete with PostScript, a specialized graphics language from Adobe Systems (Palo Alto, Cal.). PostScript has been used in products offered by many of the desktop-publishing software vendors, including Manhattan Graphics (New York), Aldus (Seattle), and Boston Software Publishers. In any case, Gregory Van Buren of InterConsult (Cambridge, Mass.) maintains that "VDI remains more appropriate for use with general-purpose graphics."

—Eric Hughes

RICH IWASAKI

"Chips that incorporate graphics standards can speed up graphics processing fivefold. This should enable a relatively inexpensive desktop system to use a more visual interface (such as icons and windows), integrate graphics with text, and devise animated programs."

Thomas Clarkson
Chairman
Graphic Software Systems

Macintosh. (This will work only with the lowest-resolution IBM displays until better digitizing hardware appears.)

If available, conversion programs can help salvage graphics produced with one of the minor standards. These standards include HALO, which has some programming language support but is now declining, and NAPLPS (North American Presentation Level Protocol Syntax), the format developed for the stillborn videotex industry.

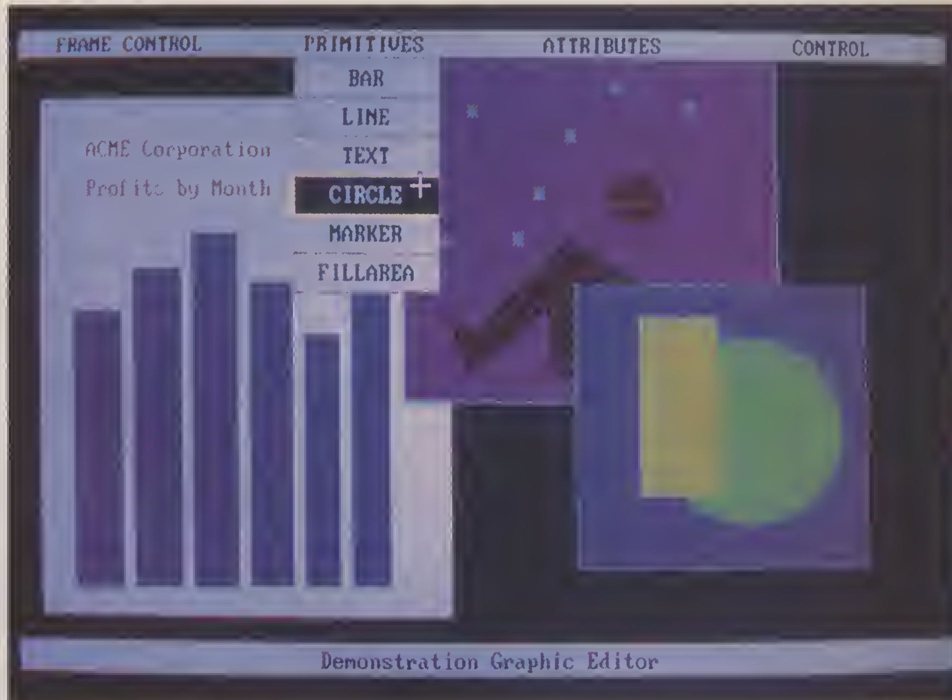
From a technical standpoint, the main obstacle to adopting a graphics standard is processing speed. Most of the older microcomputers control all graphics—whether for the screen or for the printer—with the main central processor chip. As graphics becomes more complex, this computational burden starts to overwhelm the CPU, which spends more and more time managing the screen. CPU control has often been workable for straightforward bit-mapped images, but generating and interpreting graphics primitives adds a further layer of computation. Speed problems thus make many graphics systems sluggish; Microsoft had to delay the release of Windows by more than a year while it streamlined the program, speeding up its operation.

New computers will increasingly assign a special graphics processor chip to drive the CRT and other output devices with the necessary speed. The main CPU need only generate graphics-primitive information and send it to each output device, which can then compute the actual image independently. The first important microcomputer to incorporate a graphics processor as an integral part of its design was the Commodore Amiga, although the Amiga format is unlikely to spread beyond that model, because it uses proprietary chips.

NCR Microelectronics and Hitachi have already announced chips to support some form of VDI, and all the major semiconductor manufacturers, including Intel, Motorola, and NEC, are working on graphics-processing chips.

The development of low-cost graphics chips will make every device "intelligent," able to understand graphics primitives on its own. A flexible chip design can be programmed to deal with all the common device variations and can cope with differing resolution, gray scale, color, and so on. All screen display adapters and all graphics printers are candidates for using these chips.

Consider, for example, the main problem with PostScript and similar high-performance graphics standards: the amount of computing horsepower necessary to make them work. The $6000 Apple LaserWriter, the cheapest PostScript output device so far, has a 68000-based computer with 1.5 megabytes of RAM and half a megabyte of ROM—more raw power than most microcomputers—to serve a single function: taking PostScript descriptions and turning them into a 300-dpi raster for the printing mechanism. PostScript could clearly be helped with custom processors, which could drive video screens as well as printers.



A complete graphics standard specifies not only graphics but also text and image management. Image management provides for clipping images within frames, overlaid windows, and a menu option (all shown here). This example was created with the GSS/CGI standard, which does not specify a user interface.

◆ Companies ◆

Adobe, 1870 Embarcadero, Suite 100, Palo Alto, CA 94303, (415) 852-0271

Allied Linotype, 425 Oser Ave., Hauppauge, NY 11788, (516) 434-2016

Brightbill-Roberts, 120 E. Washington St., Suite 421, Syracuse, NY 13202, (315) 474-3400

Digital Research, Box 579, 160 Central Ave., Pacific Grove, CA 93950, (408) 649-3896

Graphic Software Systems, 9590 SW Gemini Dr., Box 4900, Beaverton, OR 97005, (503) 641-2200

Microsoft, 10700 Northup Way, Bellevue, WA 98004, (206) 828-8080

Micrografix, 1820 N. Greenville Ave., Richardson, TX 75081, (214) 234-1769

Ventura Software, 25665 Tierra Grande, Carmel, CA 93923, (408) 625-5998

As the industry mulls over its future, it keeps coming back to a fundamental question. Will people actually use all these capabilities? Will the user who now has trouble figuring out how to make a printer do double spacing take on the additional work of selecting typefaces, creating headlines, and adding graphs?

The answer is most likely yes, although these changes may take some time. With a good graphics interface, the process of setting up a document complete with pictures and typefaces is actually easier than trying to cope with the "dot commands" that perform formatting in a traditional text-based word processor. What's more, most businesspeople realize that effective presentations make a difference in closing a sale or persuading a committee to take action. If a competing salesperson or the manager in the next office begins turning out polished reports with graphics, could you afford not to?

But ultimately, graphics-based computers will replace text-based systems for the same reason that television has largely superseded radio: Pictures say more than words. The world, after all, is graphic—and the computer should be nothing less than a window on the world. □

Cary Lu is microcomputer editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 70.*

Ultrafast chips at the gate

Researchers are betting on novel fabrication methods to boost computing speeds tenfold

by Herb Brody

Silicon, it's been said, is a lot like coal—cheap, abundant, and familiar, but with inherent problems that spur the search for something better. Just as energy researchers are exploring solar and nuclear alternatives—rather than simply new combustibles—the excitement in electronics is focusing not just on a replacement for silicon but on a whole new concept for making semiconductors. If present research pans out, future computers will contain transistors that switch on and off 10 times as fast as present devices, and information will travel within the computer at literally the speed of light.

New techniques can now create an unprecedented variety of crystals (orderly arrangements of atoms) by interleaving extremely thin layers of different materials, to make multilevel sandwiches—"heterostructures"—of compounds like gallium arsenide (GaAs) and gallium aluminum arsenide (GaAlAs). By controlling the thickness and composition of each layer, one can tailor the material's electrical and optical properties with a precision not possible with conventional techniques.

The use of ultrathin layers of dissimilar materials can increase the crystal's "carrier mobility," the electron speed attained as a result of a given electric field. This is accomplished by juxtaposing two materials that differ in "bandgap"—the amount of energy it takes to pluck an electron out of the bonds of the lattice so that it can conduct electricity. Atoms of an impurity, or dopant, put into the higher-bandgap layer donate electrons that "fall" into the neighboring layer of lower bandgap (electrons and other particles tend toward the least energetic state). The charge carriers then "slip along the interface at high speed, because the donor atoms are not in their path," explains Cornell electrical engineering professor Lester Eastman, a leading researcher in the field. Electrons trapped in this way encounter very little hindrance and thus can attain high speeds; in an ordinary semiconductor crystal, by contrast, an electron travels only a short distance before a collision with a dopant atom breaks its stride. Electrons in a heterostructure have been clocked at up to 20 million centimeters per second, versus 6–8 million cm/s for an ordinary silicon device and just over 10 million cm/s in thick layers of gallium arsenide, according to Eastman.

This effect was first demonstrated by AT&T Bell Laboratories (Murray Hill, N.J.) in 1978, and Japanese and U.S. companies are working to harness it for a practical device called a high-electron-mobility transistor (HEMT). The semiconductor speed record of 5.8 picoseconds (trillionths of a second) was set last fall with such a device, developed by Shin Shem Pei and colleagues at Bell Labs in collaboration with Cornell's National Research and Resource Facility for Submicron Structures. (By contrast, typical silicon transistors switch in billionths of a second.) The design of the record-setting transistor typifies the new heterostructure technologies: It consists of a gallium arsenide substrate coated on top with a thin layer of higher-bandgap alloy in which some of the gallium atoms have been replaced by aluminum ones and into which silicon has been introduced as a dopant. Only Josephson junctions, which rely not on semiconductors but on superconductors cooled to liquid-helium temperatures, have run faster.

The HEMT belongs to a class of devices known as field-effect transistors (FETs). In a FET, the flow of current between two terminals called (logically enough) the source and the drain is regulated by a voltage applied to an

Dawn of a new age in semiconductors: Gallium arsenide wafers are coated with ultrathin layers by metal-organic chemical vapor deposition (MOCVD).

EMCORE

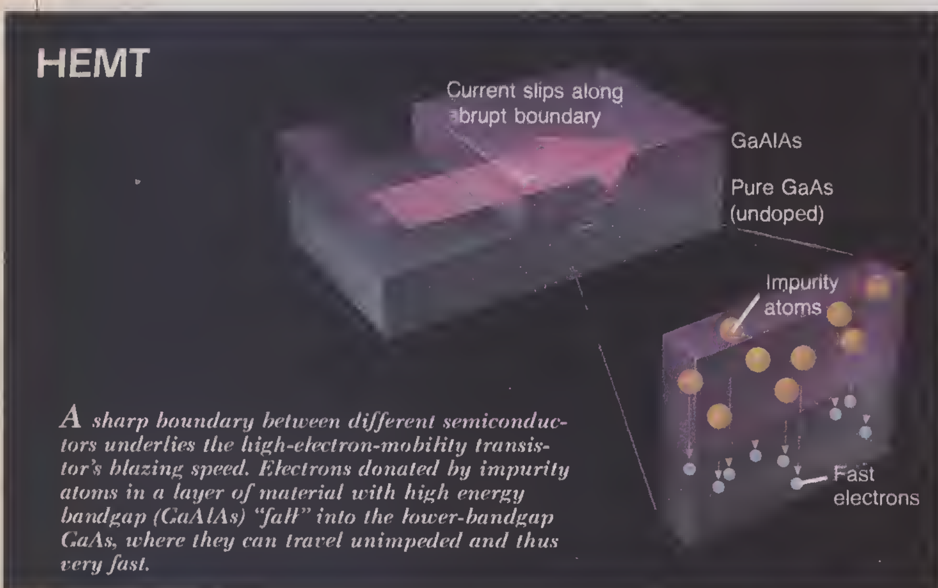
electrode called the gate. A HEMT is also known as a MODFET (modulation-doped FET), because it depends on changing material composition from layer to layer. It goes by a variety of other names as well, including selectively doped heterostructure transistor and two-dimensional electron gas (because of the charged particles' vapor-like freedom to roam within the thin layer). In fact, one wit has dubbed it the MAD—for many-acronymed device.

Another high-speed device concept—the ballistic transistor—relies on electrons traveling not within a layer but across its thickness. The switching speed of a transistor is limited by the time needed for an electron to traverse the device's middle terminal—the gate in a FET, the base in a bipolar device (the other major class of transistors). Ordinarily, electrons lose speed as they travel because they bump into atoms and each other. By making the path short enough, the electron will sail from one side to the other like a projectile, without a single collision.

Interleaving layers only a few atoms thick will yield devices that far outperform today's semiconductors.

Such ballistic transport was first demonstrated last year at IBM's Thomas J. Watson Research Labs (Yorktown Heights, N.Y.). An IBM team led by Mordehai Heiblum constructed a semiconductor sandwich: two outer layers of gallium aluminum arsenide (the transistor's emitter and collector terminals, analogous to the source and drain) and an ultrathin "filling" of gallium arsenide as the base. Electrons fall from one of the higher-bandgap GaAlAs layers into the low-bandgap GaAs interior, picking up speed like a boulder rolling down a mountainside. Heiblum made the GaAs "well" a mere 300 angstroms wide (there are ten million angstroms in a millimeter), and showed in experiments that about half the electrons launched into the device did indeed pass through to the other GaAlAs layer without slowing down.

Short switching times would grease the wheels of digital computers, where calculations are built upon huge numbers of on/off operations. Indeed, Japan's Fujitsu intends to develop a supercomputer based on HEMTs. But speedy electrons also benefit analog systems where voltage levels rise and fall very rapidly. The military, for example, is interested in developing radar with wavelengths of a few millimeters, corresponding to frequencies of hundreds of gigahertz (billions of cycles per second). Such radar can resolve finer details than can the centimeter wavelengths now in use, but present semiconductor electronics are not up to the task of amplifying the signals: The fastest silicon transistor poops out around 20 GHz, and conventional GaAs devices at about 50 GHz. General Electric has achieved the high-water mark; its heterostructure GaAs/GaAlAs transistor shows gain (amplification) at frequencies up to 80 GHz, corresponding to a wavelength of 3.75 mm, according to Jim Hwang, who heads work on advanced materials and devices at GE's electronics laboratory (Syracuse, N.Y.).



A sharp boundary between different semiconductors underlies the high-electron-mobility transistor's blazing speed. Electrons donated by impurity atoms in a layer of material with high energy bandgap (GaAlAs) "fall" into the lower-bandgap GaAs, where they can travel unimpeded and thus very fast.

ILLUSTRATIONS BY MARK E. ALSOP

Zipping electrons more quickly from point A to point B is only one way that heterostructures could lead to speedier devices. They also allow point A and B to be much closer together, permitting more circuitry per chip.

In conventional semiconductor devices, the boundaries of a feature (such as a gate in a field-effect transistor) are defined by the implantation of impurity atoms. Such doping cannot be performed with perfect uniformity, however. That's not a fatal problem in present devices, because the doping level averages out over the relatively large features. But these variations could prove to be the undoing of the more refined devices being developed. "If fluctuations occur over distances comparable to the gate length, an integrated circuit made up of such transistors just won't work," because different elements will turn on at different voltages, says David Myers, a semiconductor researcher at Sandia National Laboratory (Albuquerque).

Heterostructure (or "superlattice") devices sidestep this problem because they delineate features not by adding impurities but by changing the host material itself. Current flow is channeled along the desired paths because of the abrupt change in energy bandgaps between the bordering materials. As designers push toward gate lengths of only 0.2–0.3 micron, heterostructure transistors loom as the most likely avenue for ultra-large-scale integration, says Myers.

Fabrication methods. Researchers have long recognized the potential advantages of heterostructures but have had difficulty making them. That problem is now being solved with two techniques for growing very thin layers of crystals: molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD). Both methods can produce an enormous variety of semiconductor structures that occur neither in nature nor in other artificial fabrication processes.

In MBE, a wafer of substrate material, together with a number of tubs containing the elements that are to be deposited on it, is placed in a vacuum chamber. Heating the elements to a very high temperature causes them to vaporize. When a mechanical shutter in front of a tub opens—usually under the control of a computer programmed with the desired material structure—some of the boiled-off atoms land on the substrate, and arrange themselves in

Metal-organic chemical vapor deposition relies on reactions between gases to create the materials that coat the wafer. The structure shown in mid-fabrication consists of alternating layers of GaAs and GaAlAs, a composition used for efficient lasers as well as high-speed transistors. Because the semiconductor-bearing gases swirl around the chamber, they can coat multiple wafers simultaneously.

an "epitaxial" layer—that is, with crystal structure closely related to that of the substrate.

Before MBE, complex semiconductor structures were made with liquid phase epitaxy (LPE). Here the wafer is dipped in heated solutions bearing the atoms of interest; cooling the solution causes the element to precipitate out and coat the substrate. But LPE is limited to producing somewhat thick layers and gradual transitions between materials. MBE, on the other hand, is capable of exquisite precision. It is possible, for example, to deposit a film of one material only 3 atoms thick, and then abruptly switch to another material for another few atomic layers.

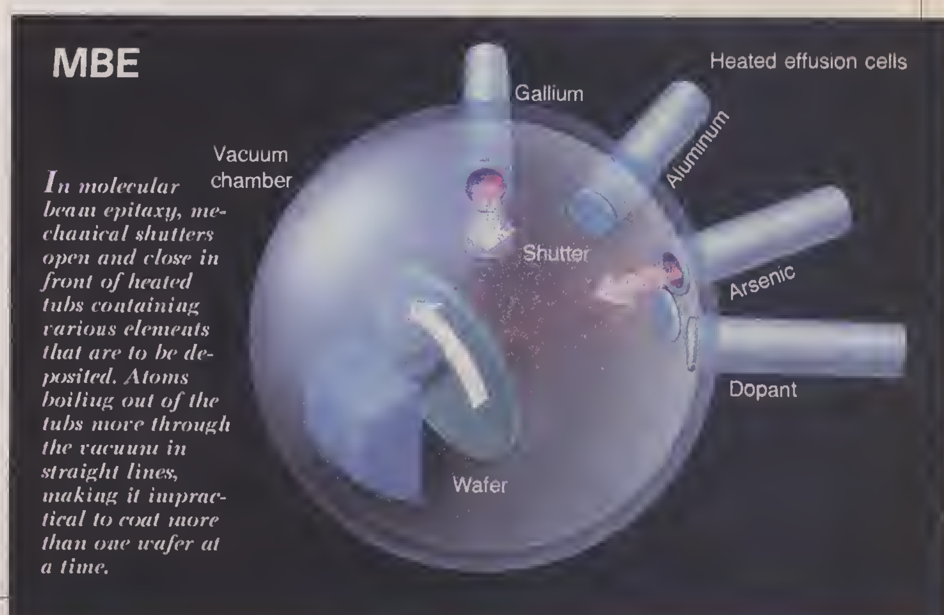
The biggest drawback to MBE is its slowness—material piles onto the substrate at the rate of about one atomic layer per second, yielding only about 1 micron per hour. Also, only one wafer can usually be processed at a time. It is this limited "throughput" that has fueled much of the present interest in MOCVD as an alternative.

Unlike MBE, MOCVD does not require a vacuum; the materials being applied come in the form of gases, at atmospheric pressure, that chemically combine on the heated surface of the substrate. Metals like gallium, aluminum, and indium come linked to organic chemical groups such as methyl (CH_3–). Arsenic and phosphorous come in their hydride forms: arsine (AsH_3) and phosphine (PH_3). The rate of crystal growth is governed by varying the flow rate of the various gases into the chamber; pumps and valves do the work of an MBE system's shutters.

Because the crystal materials come as gases that swirl around a chamber, MOCVD can coat multiple wafers at a time. The technique is therefore considered more amenable to commercial production than MBE. Several companies now market MOCVD reactors, including Spire (Bedford, Mass.), Cambridge Instruments (Cambridge, England), Crystal Specialties (Portland, Ore.), and Emcore (South Plainfield, N.J.). The reactors typically cost about $250,000, or a third what an MBE system goes for.

Proponents of MBE insist the technique will prevail, however, because comparing the economics involves more than just asking which machine costs more. For example, MOCVD's use of arsine—a gas that is lethal in part-per-million concentrations—requires a room outfitted with expensive safety equipment. Moreover, the belief that MBE is unsuited for large-scale device production is "a total misconception," according to Alfred Y. Cho, head of electronics and photonics materials research at Bell Labs. Automated systems can remove a coated wafer from the MBE chamber and insert a fresh one in less than five minutes, he notes, and some Japanese companies already use MBE to make large quantities of semiconductor lasers at low cost for compact disc players.

Lasers on chips. Indeed, much of the impetus for both of these epitaxial techniques has come from the optoelectronic community. The first practical heterostructure devices



In molecular beam epitaxy, mechanical shutters open and close in front of heated tubs containing various elements that are to be deposited. Atoms boiling out of the tubs move through the vacuum in straight lines, making it impractical to coat more than one wafer at a time.

were semiconductor lasers—the salt-grain-size chips that send lightwave telephone signals through an increasing proportion of the telecommunications network.

At the heart of these laser devices is a junction between two dissimilar semiconductors. When current flows into this junction, electrons give up energy in the form of light by falling into a vacant site, or hole, in the crystal lattice.

Most lasers to date have been made with liquid phase epitaxy and have an "active region" (the zone where the electrons combine with holes) about 1 micron thick. But the more refined structures made possible with MBE and MOCVD have led to several advances in laser performance. One important benefit is that less current is needed to make the chip "lase." Typical thick-film devices require hundreds of milliamperes; that can be reduced dramatically by fabricating "quantum wells," structures that have only recently become practical.

A quantum well is a sandwich of high-bandgap semiconductor (typically GaAlAs) surrounding a very thin film of another material with a smaller gap (usually GaAs). Electrons in the GaAlAs tend to dive into the lower energy level offered by the nearby GaAs. Once there, the electron is trapped, since the bandgap discontinuity forms a steep-sided well that prevents its escape.

Confining the charge carriers (electrons and holes) to an extremely small area raises the chance that they will recombine to create a photon of light; this probability jumps sharply for wells narrower than about 300 angstroms. (At such small dimensions, quantum mechanical effects dominate the electron's behavior; hence the term quantum well.)

The quantum well structure tremendously increases the amount of light generated for a given electrical input. Most conventional lasers put out no more than a few tenths of a watt, yet a quantum well laser has been made to generate four watts, according to Donald Scifres, president of Spectra Diode Laboratories (Mountain View, Cal.), a joint venture of Spectra-Physics and Xerox that makes quantum well lasers. (Spectra Diode's most powerful commercial laser puts out 0.2 watt).

Moreover, while conventional semiconductor lasers require about 100 milliamperes to generate a true laser beam, quantum well lasers have been built with thresholds as low as 3 milliamperes—and sub-milliamp lasers are on the way, says Robert Burnham of the Xerox Palo Alto Research Center. With such low current requirements, he says, many lasers could be ganged on a chip—a starting point for future computers that use optical, rather than electronic, logic circuits. Such systems will require a way to put many lasers on a single chip just as today's integrated circuits contain thousands of transistors. That will require extremely low power dissipation, which means the devices must operate on low currents. Quantum wells loom as a probable solution.

An electron can sail across an ultrathin material layer without a single speed robbing collision.

Another advantage of quantum well lasers is the greater control over the material structure and wavelength. MBE and MOCVD permit fabrication of lasers of precisely specified output wavelength—a function of the energy "distance" through which the electron falls when it encounters a hole. Larger gaps produce photons of higher energy and hence shorter wavelengths (that is, light nearer the blue end of the spectrum). By attaining wavelengths formerly out of bounds, quantum well lasers could replace larger and more power-hungry gas lasers in some systems.

Of particular appeal is a semiconductor laser that generates visible light, as opposed to the longer-wavelength infrared radiation that present devices put out. Shorter wavelengths can be focused to smaller spots, an advance that would, for example, increase the amount of information that can be stored on optical media such as compact discs.

Most of the success in visible-light semiconductor lasers has come from overseas. Philips Research Labs in the Netherlands used MBE to build a laser that shines a red beam of 707 nanometers; the laser contains a GaAs quantum well layer only 13 angstroms thick—about 5 atomic layers. Japan's Nippon Electric achieved even shorter wavelength—690 nanometers—with an MOCVD laser of gallium aluminum indium phosphide.

Optical computing. A computer is only as fast as its slowest part; as transistors split the second into unimaginably brief intervals, the bottleneck becomes the communication pathways that connect one set of circuit chips to another. One possible solution is to transmit information optically: Nothing travels as fast as light. To fully exploit this idea, lasers and photodetectors should reside on the same slabs of semiconductor as the logic and signal-processing circuitry.

Honeywell is working on an all-GaAs device that would process numerous electronic signals and then merge (multiplex) them to modulate a laser on the same chip. The goal is for the laser to spit out light pulses at the rate of 1 gigabit per second, says Obert Tufti, a research fellow at Honeywell's Physical Sciences Center (Minneapolis).

Another possibility is a hybrid chip that uses cheap and easy-to-work-with silicon for the substrate and for the less demanding electronic functions, reserving gallium arsenide and its alloys for ultra-high-speed work and for generating and sensing light beams. In the future, says U. of Illinois electrical engineering professor Hadis Morkoc, silicon integrated circuits may have high-speed "core circuits" of GaAs. Already, he points out, gallium arsenide HEMTs have been fabricated on the same silicon substrate as silicon transistors, without adversely affecting the latter's performance.

The advent of MBE and MOCVD has led to other optoelectronic devices as well. Some would perform functions similar to ordinary devices already on the market, but with greatly improved performance. For example, in a conventional photodetector, each incoming photon knocks loose one electron, creating an electron–hole pair. Although it is possible to boost the response by applying higher voltage so that each photon forms numerous electron–hole pairs, such an "avalanche" process introduces electrical noise that detracts from the detector's ability to sense a signal.

But an experimental photodetector recently demonstrated at Bell Labs shows the power of "bandgap engineering," says developer Federico Capasso, a physicist in the optical electronics research department. In most devices the bandgap is the same throughout the breadth and thickness of the material; that is, the energy required to separate an electron from a hole remains constant from point to point. Capasso's photodetector, however, depends on abrupt changes in bandgap for its operation. An electron liberated by an incoming photon in a layer of high-bandgap material drifts in the direction of the applied voltage. Upon encountering the boundary with a lower-bandgap material, the electron dives into that

STEVEN MANGOLD

layer, thereby acquiring enough energy to kick loose more electrons. These electrons continue a short distance and then fall into a layer with a still smaller bandgap, and so on down a bandgap staircase. At each step the electrons multiply, raising the magnitude of the output signal. Consequently a very small input of light produces a large electrical output signal, which is of use in long-distance fiber optic communication.

Capasso is also responsible for a more speculative piece of bandgap engineering that could lead to a drastic change in the way computers work. The key is a multivalued transistor—a device that can operate stably at several intermediate states between on and off. This capability might greatly reduce the number of components needed to store information in memory or to perform computations.

The trick to Capasso's design is the peculiar way electrons behave when confined within very small dimensions. Capasso envisions putting a quantum well in the base region of a transistor. As with any transistor, output would occur when electrons pass from the emitter region through the base to the collector contact. It would seem at first

"Quantum well" lasers made with MOCVD are more powerful and more efficient than ordinary semiconductor lasers, says Donald Scifres, president of Spectra Diode Labs—one of the first companies with products that rely on the new fabrication technologies.

CRYSTAL SPECIALTIES

After being sliced from an ingot, gallium arsenide wafers are polished to an ultraflat, mirrorlike finish in preparation for their use as substrates in an MOCVD chamber.

BUSINESS OUTLOOK

Gallium arsenide chips spark growth in fabrication equipment

Two fabrication processes—metal-organic chemical vapor deposition (MOCVD) and molecular beam epitaxy (MBE)—are available for creating very thin, pure films on gallium arsenide chips. In MOCVD, gases chemically react throughout a chamber and condense onto a heated substrate; in MBE, substances evaporated from the desired materials travel through an ultra-high vacuum to be deposited directly.

MOCVD equipment sales should grow from $28 million in 1984 to $86 million in 1989, according to VLSI Research (Santa Clara, Cal.). Leading players in this market include Emcore (South Plainfield, N.J.), Crystal Specialties (Portland, Ore.), Spire (Bedford, Mass.), and England's Cambridge Instruments. Sales of MBE machines—available from Varian Associates' Thin Film Division (Santa Clara), Perkin-Elmer (Eden Prairie, Minn.), France's Riber, and England's Vacuum Generators—should reach $45 million in 1989, up from $10 million in 1984.

"A war is going on between MBE and MOCVD to prove their relative advantages in the eyes of manufacturers of gallium arsenide devices," says John G. Posa, sales and marketing manager at Crystal Specialties. MBE is useful for growing extremely fine atomic layers onto a substrate, he says, but only a limited number of wafers can be handled at any one time. MOCVD can process many wafers at once, but must cope with potential safety problems posed by the use of arsine and other toxic gases.

Dale Morsette, marketing manager at Perkin-Elmer, says that the ability to control the growth and purity of thin films with great precision makes MBE more suitable for very-high-speed devices and those requiring an abrupt interface between layers of different materials. "At the least," he says, "companies can use MBE for research, to determine if the devices they want to make are feasible, and for low-volume production while the market is growing." For customized circuits, low-volume runs may be all that is needed. But Morsette points out that improvements in the efficiency of MBE—such as preparation of the substrate outside the vacuum chamber, and automated systems for loading and unloading cassettes of six or more wafers—are making higher production rates possible.

"MBE has been the leading-edge technology for fabricating a new generation of gallium arsenide devices. But the MOCVD process will make those devices commercially viable in production quantities."

Norman Schumaker
President
Emcore

"Gallium arsenide may be the best available technology for overcoming the processing limits of silicon chips. Gallium arsenide carries a premium price tag, but the new materials and fabrication techniques should cut production costs rapidly."

William Grove
Editor
In-Stat Research Letter

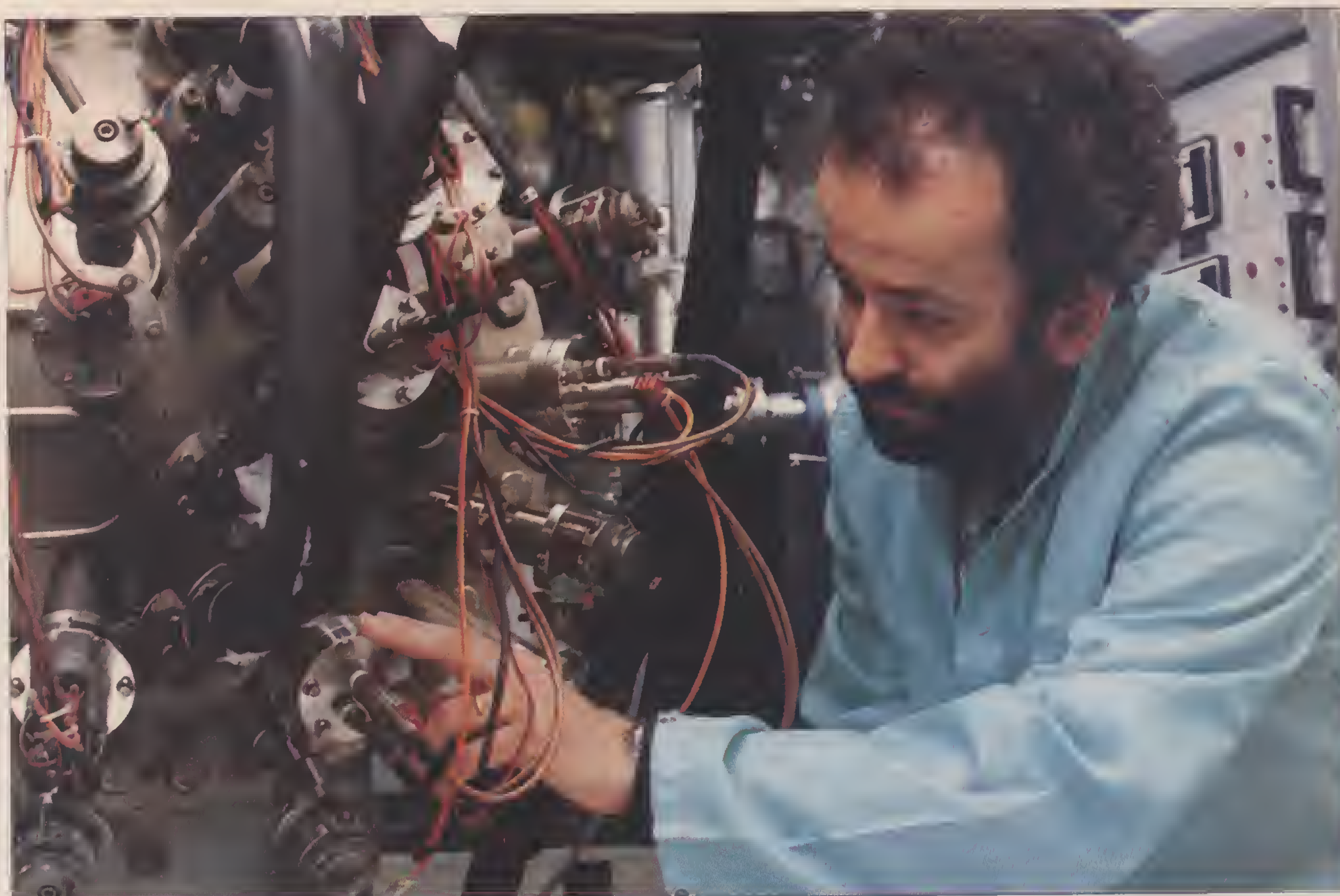
Meanwhile, MOCVD equipment is priced at $200,000–$500,000, giving it a relative cost advantage over the $700,000 average price of MBE machines. Moreover, MOCVD is being fine-tuned to produce the kind of high-speed devices that have been a specialty of MBE. For example, Posa says that within two years, MOCVD could be used to make high-electron-mobility transistors at quality levels achievable with MBE.

Demand for MOCVD and MBE machines is dependent on growth within the gallium arsenide device industry. This growth, in turn, is based on several of gallium arsenide's advantages: It has higher speed, lower power requirements, and greater resistance to radiation than silicon, and it can emit light.

Thus, for example, semiconductor lasers based on alloys of gallium arsenide are an integral part of the fast-growing markets for fiber optic communications systems and compact disc players. And gallium arsenide integrated circuits (ICs) are playing increasingly important roles in sophisticated electronic warfare equipment, commercial satellite earth stations, and electronic test equipment used for measuring high-frequency signals in real time. They should also be widely used in forthcoming models of scientific supercomputers.

The worldwide market for gallium arsenide ICs is expected to multiply from $85 million in 1985 to $2.5 billion by 1992, according to In-Stat (Scottsdale, Ariz.); by the end of the century, sales of gallium arsenide chips could make up a third of the total world semiconductor market.

At present, MBE and MOCVD are largely used to fabricate optoelectronic devices; most gallium arsenide ICs are still produced with ion implantation techniques and equipment similar to that used in high-volume production of silicon chips. But that situation is expected to change. "MBE and MOCVD will be essential for producing the next generation of very-high-speed chips," says Thomas Reeder, marketing manager at TriQuint Semiconductor (Beaverton, Ore.), a manufacturer of gallium arsenide devices. ***—Dennis Livingston***



Bell Labs physicist Federico Capasso's imaginative designs—such as a transistor with several distinct "on" states—depend on the precise control over material deposition that systems like this molecular-beam-epitaxy machine make possible.

glance that the quantum well would render the base a dead end and that the device would not work at all.

It turns out, however, that trapping a particle in an electromagnetic well is not quite the same as putting a marble at the bottom of a bowl. The marble can escape only if it acquires enough energy to leap over the side. The electron, on the other hand, can bore through the walls of the trap if the barriers are slim enough.

Crucial to the device's operation is that the ability to tunnel is not universal: Only those electrons carrying certain "resonant" energies have a good chance of making it through the barrier. It is this phenomenon of resonant tunneling that allows multilevel logic, according to Capasso.

The energy of the electrons entering the base is governed by the voltage applied between the base and the emitter. With a quantum well in the base, a steady increase in the base-emitter voltage would cause the output current at the collector to rise and fall periodically, with each peak corresponding to the brigade of resonant electrons that tunneled through. The quantum well would in effect serve as a filter, allowing passage of only those electrons possessing certain energies. Such a device might have as many as eight or ten stable output points, each signifying a different value.

Super-efficient lasers could be put on chips in large numbers for future optical computers.

Bell Labs has not yet demonstrated a resonant tunneling transistor, but Fujitsu in Japan has built one with the quantum well in the emitter region rather than the base. The resulting lack of symmetry makes the device unsuited for multistate logic. Its main advantage is the potential for greatly increased switching speed; charges travel much faster via tunneling than by ordinary conduction.

Although multilevel logic devices based on quantum effects are still far from implementation, they stand out as one of the few truly radical ideas to have emerged so far from the new semiconductor materials technologies. In contrast, devices like the HEMT, the ballistic transistor, and the quantum well laser perform the same functions as existing devices—albeit with significant improvements.

This lack of fundamentally new ideas troubles some observers. "In 1950 a lot of people thought the biggest use of transistors would be to replace receiving tubes in radios," says William R. Frensley, who specializes in advanced concepts at Texas Instruments' research labs (Dallas). "A nuclear-powered water heater in the basement seemed a lot more likely than a computer on a desk." Likewise, he says, "the party line today is that these smaller semiconductor structures will simply bring us faster devices. If this technology is to be revolutionary, it will have to solve problems we don't know we have yet." □

Herb Brody is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 70.*


THE SKY WAS THE LIMIT.

ENGINEERING WITHOUT PAPER

Manufacturers will soon be able to integrate design and production electronically in a single, unified system

by John K. Krouse

Ever since the pioneering days of computer graphics in the early 1970s, experts have predicted the impending arrival of "paperless engineering" systems, wherein all engineering work from design through production would be carried electronically via interconnected workstations. But despite rapid advances in technology, progress toward these integrated computer-aided design and manufacturing (CAD/CAM) systems has been painfully slow. "Eighty percent of present CAD/CAM systems are stand-alone workstations used exclusively for drafting," says Alan M. Christman, general manager of the Computer-Integrated Manufacturing (CIM) Division of Control Data Corp. (Minneapolis).

There are four primary technical obstacles to CAD/CAM integration:

- *The majority of today's systems use simple wire-frame modeling, a technique that describes only the edges and envelopes of an object's geometry. These methods do not provide enough data for sophisticated engineering analysis and production programming.*
- *The limited processing power of engineering workstations often will not permit the three-dimensional modeling and analysis capabilities required for integration.*
- *Slow data transfer rates between workstations have inhibited networking and the efficient flow of shared information.*
- *A lack of agreement on standards for the exchange of graphics and control signals between dissimilar systems prevents the use of a common database.*

Recent developments in both hardware and software, however, are improving the picture. Solid modeling software is providing a serious alternative to wire frames; the newer 32-bit workstations with graphics processors are rivaling the power of mainframe computers; local-area network hardware and software are speeding data transfer; and standards such as the Initial Graphics Exchange Standard (IGES) and GM's Manufacturing Automation Protocol (MAP) are gaining acceptance by both vendors and users.

Solid modeling. Because solids define the interior of parts being designed—in contrast to conventional wire-frame and surface models—ambiguities in viewing and interpreting the model when displayed on a graphics terminal are largely eliminated. And the more complete geometric representation can be applied to other CAD/CAM functions, such as finite-element analysis (for stress calculations) and numerical control (NC) programming. Thus many experts consider solid modeling the key to CAD/CAM integration.

Despite much academic research, however, solid modeling has not yet gained widespread use in industry. Until quite recently the extensive processing-time and memory requirements of solid modeling software made it suitable only for large mainframe computers and kept the cost high. Creating the models, moreover, was a time-consuming, batch-oriented process, and graphic displays suffered from slow response. But the advent of powerful superminicomputers has dramatically reduced the time and cost of processing solid models, and interactive graphics interfaces have greatly simplified and speeded model building. As a result, more than 25 vendors now offer solid modeling packages. The number of installations increased from 40 in 1982 to about 600 in 1985, and most observers expect solid modeling to become the predominant design approach in mechanical CAD/CAM by 1990.

The significance of solid modeling in integrated CAD/CAM systems lies not so much in its interactive display features as in the shared database that can be used for other engineering functions. These include computation of mass properties such as weight and volume, center of gravity, and moment of inertia. Formerly, these parameters were determined from information on engineering drawings through laborious manual calculations.

Integrating product design and manufacturing

Control Data's Integrated Computer-Aided Engineering and Manufacturing (ICEM) system combines solid modeling, wire-frame modeling, finite-element analysis, drafting, and numerical control programming in an integrated paperless engineering system. Products such as this plexiglass valve housing for an aircraft fuel system can be designed and manufactured by passing graphic data and documentation through ICEM, eliminating time-consuming drawings and reports.

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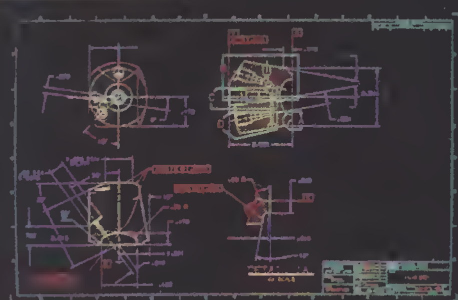

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The engineer begins by using a solid modeling program to create a geometric model. The program can then be used to "explode" the valve housing into its component parts, rotate it, create a cross section, and check for interference with related parts (1). The program also creates a wire-frame model (2) that produces the data for conventional 3-D drafting and 2-D drawings with automatic dimensioning (3).

For finite-element analysis, ICEM automatically generates a finite-element mesh (4) from the solid model. The results of thermal or stress analysis can be shown graphically. Here (5) a cross section shows the internal stresses generated by fuel pressures in one of the inlets. The scale on the right indicates stresses of up to 7113 psi. Depending on the results of the analysis, the design may be revised and the analysis repeated until the performance is satisfactory.

When the design is complete, ICEM can generate the control tapes needed by automatic machine tools for machining the valve housing. ICEM will also produce the necessary setup data (6) for a specific machine tool. In setting up the numerical control program, production engineers can preview the cutter paths to optimize them and prevent interference. In the two views shown here (7), the valve housing (yellow) is displayed as it would appear when being machined from a solid plexiglass rod held in a fixture (solid white lines). The tool paths are shown as dotted colored lines. Finally, the valve housing is produced automatically on a machine tool (8).

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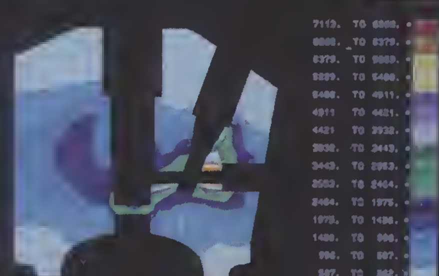

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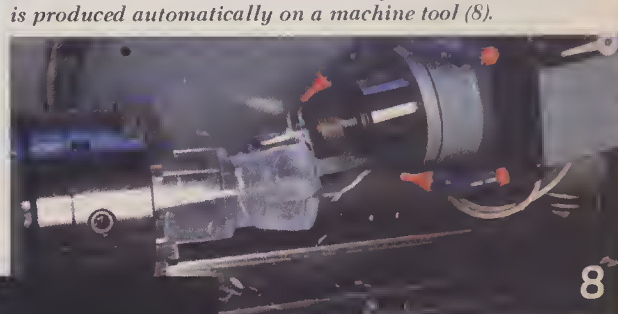

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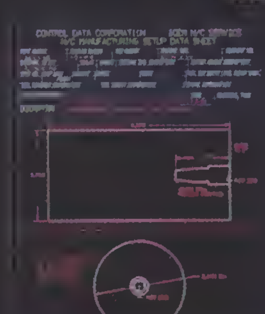

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Leading players in the integration stakes

Very few companies have the resources to offer complete paperless engineering systems today. Indeed, only the largest CAD/CAM suppliers are likely to come close, although several will offer links between their own systems and those of other makers. The following companies are the principal CAD/CAM suppliers:

IBM

Armonk, NY 10504, (800) 426–3333. Reportedly the sales leader in CAD/CAM systems, probably because large customers are sensitive to the financial stability of vendors and the need for compatibility with existing data-processing systems. Offers a full range of CAD/CAM software for PCs, intelligent terminals, and mainframes. Recently introduced its RT personal computer line of engineering workstations, which incorporate RISC (reduced-instruction-set computer) technology.

INTERGRAPH

One Madison Industrial Park, Huntsville, AL 35807, (205) 772–2000. The number-two CAD/CAM vendor after IBM, Intergraph has a solid reputation among experienced users. Offers well-tried software on DEC VAX computers and its own proprietary dual-screen graphics terminals. Recently introduced a 32-bit UNIX-based workstation for stand-alone use or interconnection to a host computer.

COMPUTERVISION

201 Burlington Rd., Bedford, MA 01730, (617) 275–1800. Former industry leader has recently reorganized to stem losses resulting from decline in demand for CAD/CAM software available only on Computervision computers. CADDS 4X software is being rewritten for UNIX. Also offers MEDUSA for DEC VAX and Personal Designer for IBM PC.

GE CALMA

501 Sycamore Dr., Milpitas, CA 95035, (408) 434–4000. Former industry leader whose share has declined since being acquired by GE. Strong in automated drafting systems and now offers a wide range of products from solid modeling to NC programming. Another GE subsidiary, GE CAE International (Milford, Ohio) provides the advanced CAD/CAM software offered by Calma.

McDONNELL DOUGLAS

PO Box 516, St. Louis, MO 63166, (314) 232–0232. Building on its in-house design and manufacturing experience, McDonnell Douglas offers a line of CAD/CAM software that will run on IBM, DEC, and Data General computers. The open architecture of the software allows users to integrate their own applications easily. Becoming active in PC-based CAD/CAM systems.

PRIME COMPUTER

Prime Park, Natick, MA 01760, (617) 655–8000. Strengthening its efforts in CAD/CAM with some success. Mechanical design software based on Computervision's MEDUSA can be linked to software for engineering analysis and materials requirements planning. Also offers terminal and network products for communication with IBM systems. Appears to be well positioned for further CAD/CAM integration.

CONTROL DATA

8100 34th Ave. S., Minneapolis, MN 55420, (612) 853–8100. Strong on large-scale, powerful computers supporting many workstations. Powerful proprietary CAD/CAM software that can be integrated with customer's in-house systems has been well accepted by large users.

HEWLETT-PACKARD

3000 Hanover St., Palo Alto, CA 94303, (415) 857–1501. Currently offers a diverse mix of workstations, computers, and uncoordinated software packages. Recent reorganization of company may help HP develop a badly needed integrated set of CAD/CAM systems for both mechanical and electronic design.

Source: CAD/CAM, CAE Survey, Daratech, (Cambridge, Mass.)

One of the most powerful computer analysis techniques being integrated with solid modeling is finite-element analysis, a process of separating a structure into simple elements whose stress and deflection characteristics can be determined by differential equations. The behavior of the entire structure can be analyzed by solving the set of simultaneous differential equations for all the finite elements. The generation of finite-element models and the solution of the resulting equations, typically numbering in the hundreds or thousands, requires considerable computer power and time. Because solid models contain most of the information required to generate a finite-element model, the latter can be generated with minimal user interaction.

Solid modeling is also having a significant impact on direct interfaces with manufacturing, particularly numerical control, where specially coded programs control machine tools. When numerical control technology was first developed in the 1950s, machine tool instructions were generated entirely by hand from engineering drawings. Later, programming languages were developed so that the user could enter a description of the part's geometry and let the computer determine the cutter path automatically.

At present, some CAD/CAM systems use wire-frame and surface models as a basis for producing NC instructions, thus eliminating the translation of data from engineering drawings and other documentation. But because conventional wire-frame and surface models do not contain enough information, extensive user interaction is still required. Consequently, work is under way to integrate solid models with NC programming and process planning, creating a "generative" programming system that will require virtually no human input except to verify the final results.

Ultimately, generative programming will recognize the solid model of the part, identify material to be removed from raw stock, select the tools required, determine machining parameters such as feed rate and spindle speeds, establish the proper sequence of work elements, and determine optimal tool paths while avoiding collisions with tooling clamps and fixtures. After NC instructions are developed, the machining process will be simulated by an animated solid model displayed in color on a graphics terminal. With this display, the user can check for problems and make any necessary changes. One

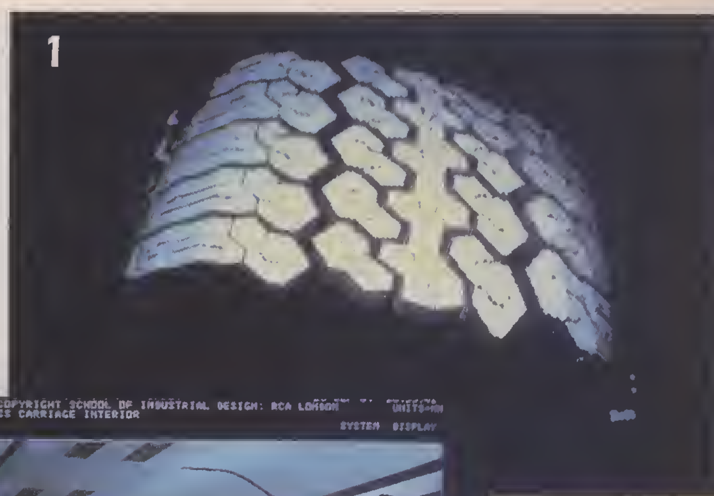
of the first generative systems, Cimplex, from Automation Technology Products (Campbell, Cal.), is undergoing tests at Ingersoll Milling Machine and LTV's Vought Aero Products Division (Dallas).

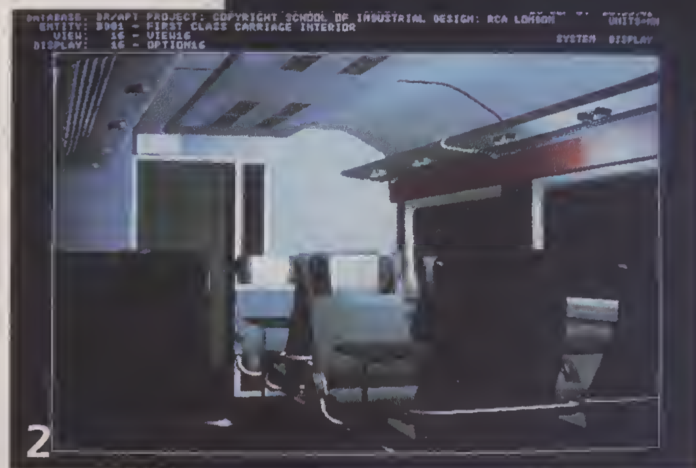
Workstations. Just as crucial as better software is better hardware. Until recently, engineering workstations often performed relatively simple functions like automated drafting, with more complex tasks handled by a remote mainframe computer. But the latest 32-bit workstations, such as the Iris 2400 from Silicon Graphics (Mountain View, Cal.) and the Sun 3/160 from Sun Microsystems (Mountain View), have the speed and memory capacity to compute and display realistic simulations without the aid of a larger computer. A color shaded model of a robot arm, for example, can display production movements smoothly; the jerky motion common in earlier graphics systems is gone. Moreover, the path can be analyzed to detect any interference from surrounding parts.

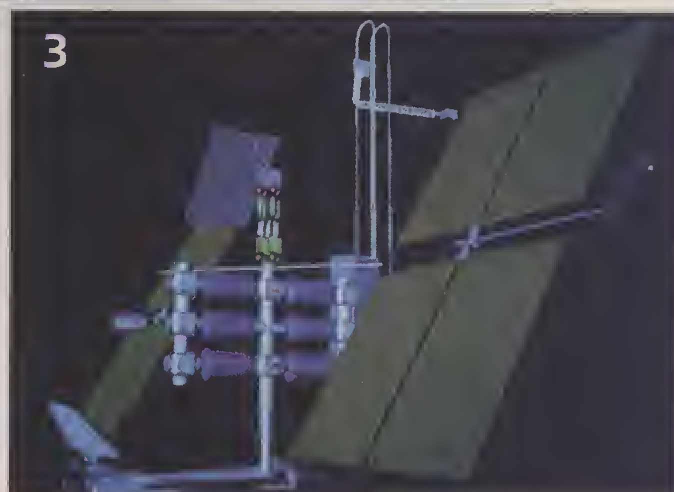
The older workstations performed geometric processing in software, but the new high-powered workstations use graphics coprocessors to perform these operations much faster. For example, generating a view of a complex solid model might require up to 30 minutes if performed with software on a computer such as the VAX-11/780; with a graphics coprocessor, the same display might take less than a second to generate. Performing display operations locally with such graphics processors rather than remotely through software is probably having its greatest impact in the area of solid modeling, where shaded image displays are now being generated in less than 1% of the time required on a host computer.

Networking. The new generation of workstations is also providing direct links between engineering areas such as design, analysis, manufacturing, and testing. Improved communication features allow data to be transferred rapidly: Rates of 10 megabits per second are typical for today's 32-bit workstations connected in a local-area network, whereas older communication systems commonly used with minicomputer-based systems are restricted to the kilobit-per-second range. Consequently, a local-area network can quickly transmit huge data files to interconnected workstations, making the same information available almost instantaneously to a large number of users. This level of networking is indispensable to the shared database of integrated CAD/CAM.

Solid modeling moves into production







The advent of powerful 32-bit engineering workstations is moving solid modeling from the R&D lab into design and production in a wide range of industries. For example, the Geomod program from Structural Dynamics Research Corporation has been used to design (1) tire tread for Goodyear, (2) railroad car interiors for British Railways, (3) space stations for Boeing Aerospace, and (4) printer mechanisms for NCR. Similar solid modeling programs are available from computer makers, such as Control Data, IBM, and Prime, and from CAD/CAM suppliers, such as Applicon, GE Calma, and Matra Datavision.

GE/SDRC

The up-and-comers in CAD/CAM tools

As in many high technology areas, innovations in CAD/CAM often come from relatively new companies, some of them started by engineers and executives from the larger, more established firms. While such companies may lack the resources of the established suppliers, they often seek market niches that are not covered by the bigger companies and may offer hardware and software tools that can solve specific integration problems. Here are some innovative companies to watch:

ALIAS RESEARCH
111 Queen St. E., Toronto, ON N5C 1F2 Canada, (416) 362–9181. Developer of an advanced 3-D graphics system based on Silicon Graphics' IRIS workstation. System has been adopted by GM's Advanced Aerodynamics Design Group for designing automobile bodies.

AUTODESK
2320 Marinship Way, Sausalito, CA 94965, (415) 331–0356. Producer of leading CAD system (35,000 licensed users) for IBM PC and compatibles. Offers extensive interfaces to large CAD systems.

AUTOMATION TECHNOLOGY PRODUCTS
1671 Dell Ave., Campbell, CA 95008, (408) 370–4000. Founded by former Calma executives, ATP offers IBM-based integrated software for designing and manufacturing mechanical parts via a common database.

CELERITY COMPUTING
9692 Via Excelencia, San Diego, CA 92126, (619) 271–9940. Makers of very high-speed Unix-based engineering workstations with sophisticated mechanical design software tools such as ANSYS, PATRAN, and NASTRAN.

CIMLINC
700 Nicholas Blvd., Elk Grove Village, IL 60007, (312) 362–9181. Previously called Cadlinc, Cimlinc markets a range of software tools and workstations for computer-integrated manufacturing of discrete parts.

COGNITION
900 Tech Park Dr., Billerica, MA 01821, (617) 667–4800. New company founded by a group of CAD veterans. First product is a solid modeling system based on an IBM PC/AT equipped with a high-resolution graphics display.

CUBICOMP
3165 Adeline St., Berkeley, CA 94703, (415) 540–5733. Offers a series of wire-frame and solid modeling software packages for the IBM PC with translators to Autocad and Versacad drafting software.

GRAFTEK
PO Box 9014, Boulder, CO 80301, (303) 449–1138. Relatively well established supplier of sophisticated software for mechanical design, NC programming, and plastic injection molding applications. Programs run on a variety of 32-bit engineering workstations.

MATRA DATAVISION
30 Commerce Way, Woburn, MA 01801, (617) 938–1230. U.S. subsidiary of French electronics company. Offers a series of CAD/CAM packages based on the Euclid solid modeling program. Recently demonstrated direct machining from solid models.

MEGACADD
401 2nd Ave. S., Seattle, WA 98104, (206) 623–6245. Makes a 3-D drawing package for the IBM PC with links to Autocad and other two-dimensional drafting programs.

TASVIR
1091 Spierlin Rd., Mountain View, CA 94043, (415) 964–7000. Recent start-up offering an IBM PC–based wire-frame modeling package said to be compatible with Computervision's long-established CADDS 4X software.

T&W SYSTEMS
7372 Prince Dr., Suite 106, Huntington Beach, CA 92647, (714) 847–9960. Became a pioneer of microcomputer CAD with Cadapple for the Apple II. Now offers Versacad for the IBM PC and compatibles.

Two basic types of networks are used for interconnecting CAD/CAM workstations: star configurations, which connect workstations through a central master node that controls all data traffic, and ring configurations, which transmit data serially around the network from one workstation to another so that each workstation can monitor all data communications. In principle, star and ring configurations could be used to connect huge numbers of workstations together. But because each data transmission takes a finite amount of time to complete, expanding the network can lead to saturation, with noticeable delays in responding to operator commands. This is especially true in applications that require a lot of computation, such as finite-element analysis and solid modeling. Consequently, local-area networks for CAD/CAM systems generally have fewer than 10 workstations.

One way to avoid such delays in local-area networks is with a "token bus." To prevent network hogging and ensure that all workstations have an opportunity to transmit data, a special access code called a token is passed sequentially from one workstation to another. The network allows only the workstation with the token to transmit data, and then only for a predetermined length of time. Receiving workstations examine each message and take action when they recognize their own address. Otherwise, the message is ignored and passed on to the next station.

Exchanging graphics. One of the biggest obstacles to CAD/CAM integration has been the lack of a common graphics standard. Much of the data generated by an Applicon system, for example, couldn't be entered directly into a Computervision system. Thus several vendors and federal agencies have developed a standardized format known as the Initial Graphics Exchange Specification to at least allow dissimilar systems to "talk" to each other. In this approach, the transmitting system translates data into a second language—a so-called IGES neutral file—that can be sent to different systems; translators at the receiving end

reformat the data into the proper form.

The main drive for a graphics exchange standard came originally from two government projects—the NASA-sponsored Integrated Program for Aerospace Vehicle Design (IPAD) and the U.S. Air Force Integrated Computer Aided Manufacturing (ICAM) project—aimed at integrating CAD/CAM systems for aerospace work. IGES was first published in January 1980 as a National Bureau of Standards report, and it was formally adopted as a national standard in September 1981. So far, 15 vendors supply IGES translators as part of their software packages: Applicon, Auto-trol, Bausch & Lomb, Calma, Computervision, Control Data, Engineering Systems, Gerber, Graftek, IBM, Intergraph, Matra Datavision, McDonnell Douglas, MCS, and Prime.

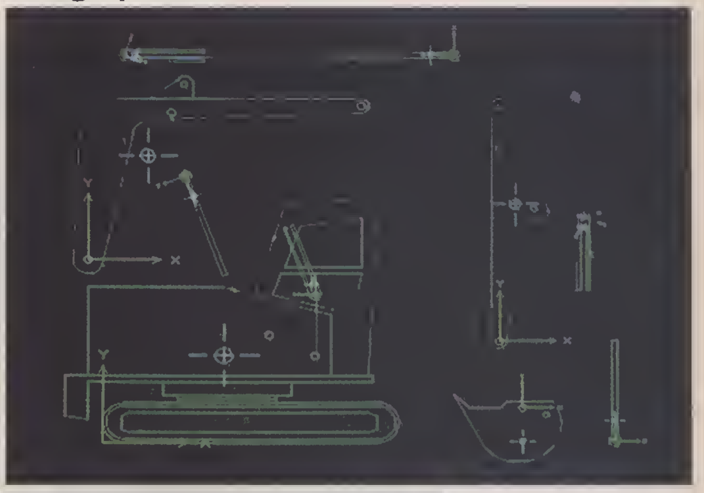
Moreover, at least 18 other CAD/CAM system vendors plan to offer IGES translators in the future. And several companies with extensive in-house CAD/CAM systems and proprietary software, including John Deere, Ford Motor Company, General Electric, General Motors, Lockheed, Martin Marietta, Structural Dynamics Research, and Westinghouse, are writing their own IGES translators.

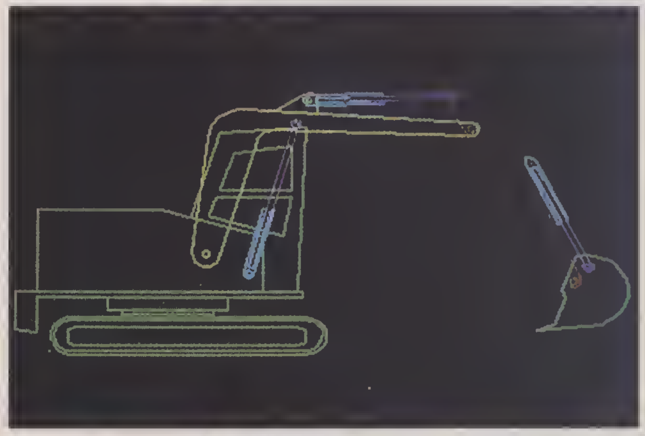
The initial geometric data-transfer capabilities of IGES have recently been extended to include finite-element modeling data. The new version also covers printed circuit board data. A future version now under development is expected to cover even broader applications, including solid modeling and architectural models.

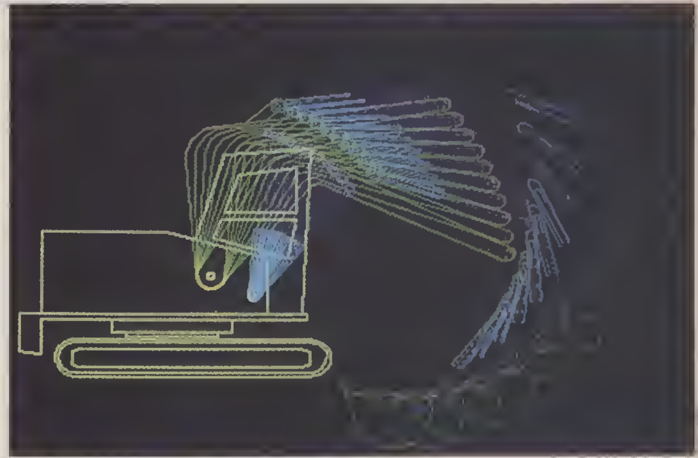
Future integrated systems will make extensive use of personal computers. Until now, PC CAD systems functioned primarily as stand-alone units, but a growing number of PC CAD vendors are expected to include IGES translators in their systems within the next year. Vendors have been slow to adopt them, because they consume so much computing power. One of the first translators to become available, Versalink from T&W Systems (Huntington Beach, Cal.), lets users move drawing files in either direction between the vendor's VersaCAD IBM PC–based drafting system and any other system with an IGES interface.

Rather than adopt IGES, some personal computer CAD vendors are developing independent interface capabilities. Control Data offers the Micropost communications program that ties Cyber mainframes to IBM PCs running the CDC PCAD electronics package. Similarly, FutureNet markets an interface linking its IBM PC–based Dash-1 schematic design system to GE's mainframe-based Tegas test-generation and -simulation system. And Autodesk

The graphic test-bed







APPLICON

Many CAD/CAM packages contain programs for simulating mechanical behavior so that the design engineer can check the movement of linkages and structures on a graphic display. In this design of a backhoe, for example, the individual linkages are first specified by the designer (top) with a conventional drafting program. The components are then assembled into a complete model (center), which can be animated to make sure the linkages work together correctly (bottom).

PCs, solid modeling drive CAD/CAM sales

Computer-aided design and manufacturing (CAD/CAM) systems enable engineers to rapidly design mechanical parts, analyze them to close tolerances, and directly generate machining instructions. By thus avoiding time-consuming and expensive manual drawing and prototype work on the shop floor, companies can significantly reduce the time and cost of developing new products. As this advantage takes CAD/CAM into more and more industries, revenues from CAD/CAM sales should rise from an estimated \$3.5 billion in 1985 to \$12.7 billion by 1990, according to Daratech (Cambridge, Mass.), a market research firm.

Until recently, the CAD/CAM industry predominantly marketed stand-alone machines. Now, however, most vendors offer systems in which four or five workstations operate under the direction of a central 32-bit minicomputer. IBM (Armonk, N.Y.) leads the industry with 21.4% of the market. The rest of the market is largely divided among Intergraph (Huntsville, Ala.) with 15%, Computervision (Bedford, Mass.) with 12%, GE Calma (Milpitas, Cal.) with 6%, and other suppliers.

The industry is currently in transition from the 1980–85 period, when the annual compound growth rate was nearly 37%, to an era of lower, but still rapid, expansion. Revenues are expected to increase by 29% per year over the remainder of the decade, according to Charles Foundyller, president of Daratech. The success of vendors during this period, he says, will depend on how well they market new and competitive product lines, particularly those involving solid modeling software and systems based on personal computers.

Solid modeling software generates a database that can be effectively shared to support a variety of functions—including structural analysis, mechanical simulation, and numerical control programming—needed throughout the CAD/CAM process. Such software enables designers to describe the volume and mass of mechanical parts on the computer—a considerable improvement over the edges and corners provided by other kinds of CAD software. "In the past, the computing power needed for solid modeling was often prohibitive," says Joseph Kormos, product manager for solid modeling at GE CAE International (Milford, Ohio). "But as hardware prices drop and the processing power of workstations increases, this opens the way for increased sales of solid modeling packages to more engineers."

SPIDER MARTIN

Strategic Inc. (Cupertino, Cal.), a market research firm, anticipates that solid modeling will dominate design applications by the end of the decade. Sales are expected to increase from \$9 million in 1984 (2% of \$438 million in total CAD software revenues) to \$900 million by 1989 (25% of the anticipated \$3.6 billion software market). The major CAD/CAM firms generally sell solid modeling software obtained from CAE International and other specialists.

Personal computer systems offer a way for companies to obtain basic CAD features such as 2-D drafting, which makes up the bulk of engineering work, at a relatively low cost (usually less than \$15,000). Such systems are slower and handle simpler problems than their full-size counterparts, "but they have such a favorable price/performance ratio compared to large, multiuser machines that sales are rapidly increasing to small manufacturers and machine shops, as well as to some larger corporations," says Tom Lazear, president of T&W Systems (Huntington Beach, Cal.), which offers CAD software for personal computers.

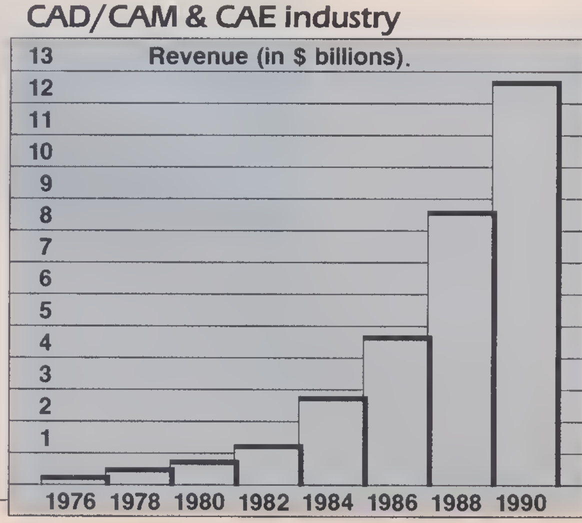
"Over the next few years, major players will be those who offer CAD/CAM systems with friendlier interfaces. Using technology such as 32-bit microprocessors, million-megabyte memory chips, and optical disc storage, these systems will be available to relatively unsophisticated users."

Robert A. Glasier
Executive Manager
Product Marketing
Intergraph

While their integration into CAD/CAM networks is only just emerging, personal computer files can be transmitted to larger machines using software that ensures compatible formats. Personal computers also offer computer-aided design tools to the 80% of designers who do not presently have access to larger systems. Lazear adds that "although revenues from sales of smaller systems are only a small part of the industry as a whole, their impact is more substantial. Most established vendors are now entering this market, which will require changes in sales strategies previously geared to promoting more expensive equipment."

—John Krouse

CAD/CAM & CAE industry



(Sausalito, Cal.) has a translator that links its popular PC-based AutoCAD drafting package to VAX-based Intergraph systems.

Factory floor integration. Integrated CAD/CAM systems are especially difficult to implement in heavy-manufacturing plants that have many different types of devices such as programmable controllers, NC machines, robots, and vision systems. General Motors, for example, has over 40,000 of these devices now installed and plans to invest $40 billion over the next four years to bring the total to 200,000 units. GM estimates that connecting and reconnecting such equipment to reflect operating changes has increased its automation costs by 50%, with most of these expenses for wiring, hardware interfaces, and custom software.

To alleviate this problem, GM has developed the Manufacturing Automation Protocol—a set of hardware and software specifications governing the exchange of data between computerized devices. MAP links incompatible devices in a token-bus local-area network with a single multichannel coaxial cable, and it provides a common syntax for data communication. Ultimately the protocol is expected to link every aspect of automobile production, from design to final assembly. Current plans call for much of MAP to be implemented in the form of custom integrated circuits, which GM believes will lower networking costs by half and cut the time required to implement integrated automation systems by a third.

The first public demonstration of MAP, involving GM and seven MAP equipment suppliers (IBM, DEC, Motorola, Hewlett-Packard, Concord Data Systems, Allen-Bradley, and Gould Modicon), took place at the National Computer Conference in Las Vegas in July 1984. At the Autofact 85 show in Detroit last November, more than 20 MAP vendors collaborated with GM and Boeing in a quarter-acre factory-in-miniature exhibit demonstrating not only a factory-based MAP network but also "internetworking" with Boeing's Technical and Office Protocol (TOP). TOP is a series of specifications for data networking in technical and administrative offices. It will eventually offer specifications for file transfers (of documents, spreadsheets, and graphics), for distributed databases, and for electronic mail. TOP shares a core of communications protocols with MAP, so the two networks can be linked, unifying design, administration, and manufacturing in a single comprehensive network.

The MAP specification is expected to be embraced by manufacturing industries because it incorporates so many data-communication standards that are already available, such as IEEE 802.2 Ethernet, IEEE 802.4 token-ring passing, Internet from the National Bureau of Standards, and GM's Manufacturing Message Format Standard (MMFS). Tying the entire system together is the general model for data communication developed by the International Standards Organization, based in Geneva. This so-called Open System Interconnect (OSI) architecture is a modular approach that allows new standards to be plugged into the overall communication system with minimal disruption. The system is hierarchical, with seven layers that each specify particular data-processing and communication tasks—from the physical, electrical, and mechanical network connections, to the software and standards for application processes and management functions.

GM's immediate plans are to install MAP at pickup truck assembly plants in Fort Wayne, Ind., Oshawa, Ont., and Pontiac, Mich., the new Buick-Oldsmobile-Cadillac assembly plant in Hamtramck, Mich., and the Fisher Body tool and die plant in Marion, Ohio. Probably the most extensive application of MAP is planned for the 60,000-square-foot automated machining complex at GM's Saginaw Steering Gear factory (Saginaw, Mich.), where it will be used in making four-wheel-drive axles. The plant is scheduled to become fully operational by the end of the year, with a MAP network linking all 40 manufacturing cells. Then, in 1987, a central factory control system is planned to schedule changeovers from one type of axle to another, downloading the new programs automatically into the cell computers. Because all information will be stored and transmitted electronically instead of on paper, the downtime required for a changeover will be reduced from three days to less than 10 minutes. Ultimately, MAP will dominate GM's manufacturing. "Within the next five years, the majority of our plants will have MAP capability," says vice-president Robert J. Eaton.

At Chrysler, more than 3000 users in 18 design centers share a huge engineering database on a network of 550 workstations connected to 27 large computers.

Several other firms are also planning MAP networks. Eastman Kodak plans to install one in its research building at Kodak Park (Rochester, N.Y.) to develop and produce photographic film, chemicals, and paper. Ford also plans to implement the protocol, starting with an electric motor plant in Rawsonville, Mich., and the engine division flexible automation sites in Dearborn, Cleveland, and Windsor, Ont.

One of the largest CAD systems in the automobile industry is at Chrysler, with 550 workstations in 18 "design and development" centers connected to 27 CDC Cyber mainframes. The network allows a design database to be shared by more than 3000 users. Over 60% of the engineering design work at Chrysler is done on the integrated system, with remarkable increases in productivity. For example, according to a Chrysler spokesperson, the engineering drawings for the basic steering and suspension geometry in the 1984 models took only 15 minutes to produce, versus three months for the same work in 1956.

Chrysler is currently extending its system into manufacturing. In the network under development at Chrysler's technical center, information on vehicles from design through production will be accessible via a shared database. The system, which is expected to go on line this year, will link DEC, Apollo, and CDC computers with specially developed Chrysler/GE Calma software, according to Robert J. Piccarilli, Jr., director of manufacturing engineering.

Another industry heavily dependent on CAD is aerospace. At Boeing facilities in Auburn, Wash., and Wichita, Kans., for example, manufacturing operations are being linked directly to the company's data centers. Specially developed IBM computers process information received from remote mainframes in Boeing data centers and feed it directly to machine tools for parts manufacturing. Over the next five years, the 500 similar systems will be implemented and linked by local-area networks.

Moreover, Martin Marietta (Orlando, Fla.) makes extensive use of integrated CAD in designing and analyzing missiles such as the Pershing, Patriot, and Hellfire. In 1976, the company purchased a CADAM 2-D drafting system from Lockheed California. In 1980, the Supertab finite-element modeler from Structural Dynamics Research was added to the IBM host mainframe and an Applicon Bravo 3-D drafting system was installed in 1981. The firm ac-

quired a Geomod solid modeler, made by Structural Dynamics Research, in 1982. Also in the system are a Computervision CADDS-4 system and several VAX-11/780 minicomputers with Lexidata and Tektronix terminals. Martin Marietta's engineers have successfully assembled these products into one of the nation's largest integrated CAD-/CAM design systems.

Using this system, engineers can develop the 3-D geometry of missile components, create finite-element meshes and analyze them with programs such as MSC/Nastran, and produce engineering drawings. Moreover, Geomod is being used to analyze solid propellant burn rates, a critical factor in calculating the thrust and trajectory of tactical missiles. Because of the speed with which the computer model shows the burn areas and remaining propellant, engineers are able to determine cavity pressure as a function of time in only one day—instead of the two weeks required with manual computations and drawings.

The firm is also developing an on-line IGES graphics database. This Martin Integrated Neutral Graphics and Engineering Language (MINGLE) will automatically feed parts definitions to downstream systems so that other computers can automatically generate bills of materials and purchase orders. It will also enable geometry data to be transferred more efficiently between the Geomod, Supertab, Computervision, Bravo, and CADAM systems, without requiring engineers to repeat the effort of defining the part.

General industry. Integrated CAD systems are also transforming a wide variety of other industries. For example, Magnetic Peripherals Inc. (MPI) in Minneapolis anticipates a $5 million saving over the next seven years using a Control Data ICEM (Integrated Computer-Aided Engineering and Manufacturing) system, which combines 3-D design, 2-D drafting, finite-element modeling, and NC programming software into an integrated package. MPI, which uses the system to design and manufacture high-precision recording heads, carriages, and spindles for computerized mass-storage systems, reports that engineering drawings can now be produced twice as fast as before. And the overall design process has been speeded up by a factor of four: When parts are designed with solid modeling, the geometric data generated are automatically applied to later stages of design and fabrication.

"The most obvious saving comes from drawing a part just once," says Roger Brunes, manager of mechanical design/CAD services at MPI's Twin Cities Disk Division. "Before we started using the CAD system, we would redraw a single part up to eight times to meet the various levels of design documentation. Now, we have not only speeded up the design process but we have the tools for rapidly generating alternative designs." Thirty-seven workstations are linked to the Cyber mainframe in an expandable network that will eventually include terminals at remote MPI plants in Omaha, Neb., Rapid City, S.D., Aberdeen, S.D., and other Minneapolis-area facilities, says Brunes.

Millitech (South Deerfield, Mass.) uses a Bruning CAD system to develop electro-optical communication systems, with lenses and mirrors surface-finished to 1-micron accuracy for sending and receiving laser signals over long distances. "CAD/CAM gives us the high precision that we just cannot achieve through manual methods," says Trent A. Poole, chief mechanical engineer at Millitech. "Using the zoom feature, for example, we can go into a small area for doing intricate work and then back off to see the entire system, maintaining the same high accuracy throughout."

"The growth in integration will be steady, but we have to keep in mind that successful implementation involves changes in company culture as well as computer systems."

The entire product development process at Millitech is carried out without the need to enter or extract information from engineering drawings on paper. First, physicists at a workstation lay out the optical system, specifying surface curvatures and placement of mirrors and lenses. This information is then sent to a CAD workstation, where design engineers assign drive trains, housings, and support structures. Next, an operator at a CAM workstation uses the design as a basis for creating NC programs to machine the parts. Finally, these instructions are sent directly to a computerized numerical control (CNC) machining center for fabricating the parts.

Emhart (Windsor, Conn.) uses an Applicon Bravo system to consolidate data from over 40,000 engineering drawings in designing and manufacturing custom bottle-making equipment. "We justified this system purchase based on improvements in drafting productivity," says Jim Sheehan, Emhart's engineering services manager. "Now we realize the value also lies in the database and the system's data management capabilities." For example, the database enables Emhart to standardize components through a parts library and produce new designs quickly just by specifying dimensions. Nearly 80% of new designs are generated in this manner, says Sheehan; the system doubled design productivity in its first month of use. The firm plans to link the system in Windsor to facilities in Zurich, Switzerland, and Sundsvall, Sweden, for faster transmission of design revisions. Currently, engineering changes take at least six weeks to be mailed, updated, approved, and implemented. With the network, changes are expected to be processed in only two or three days.

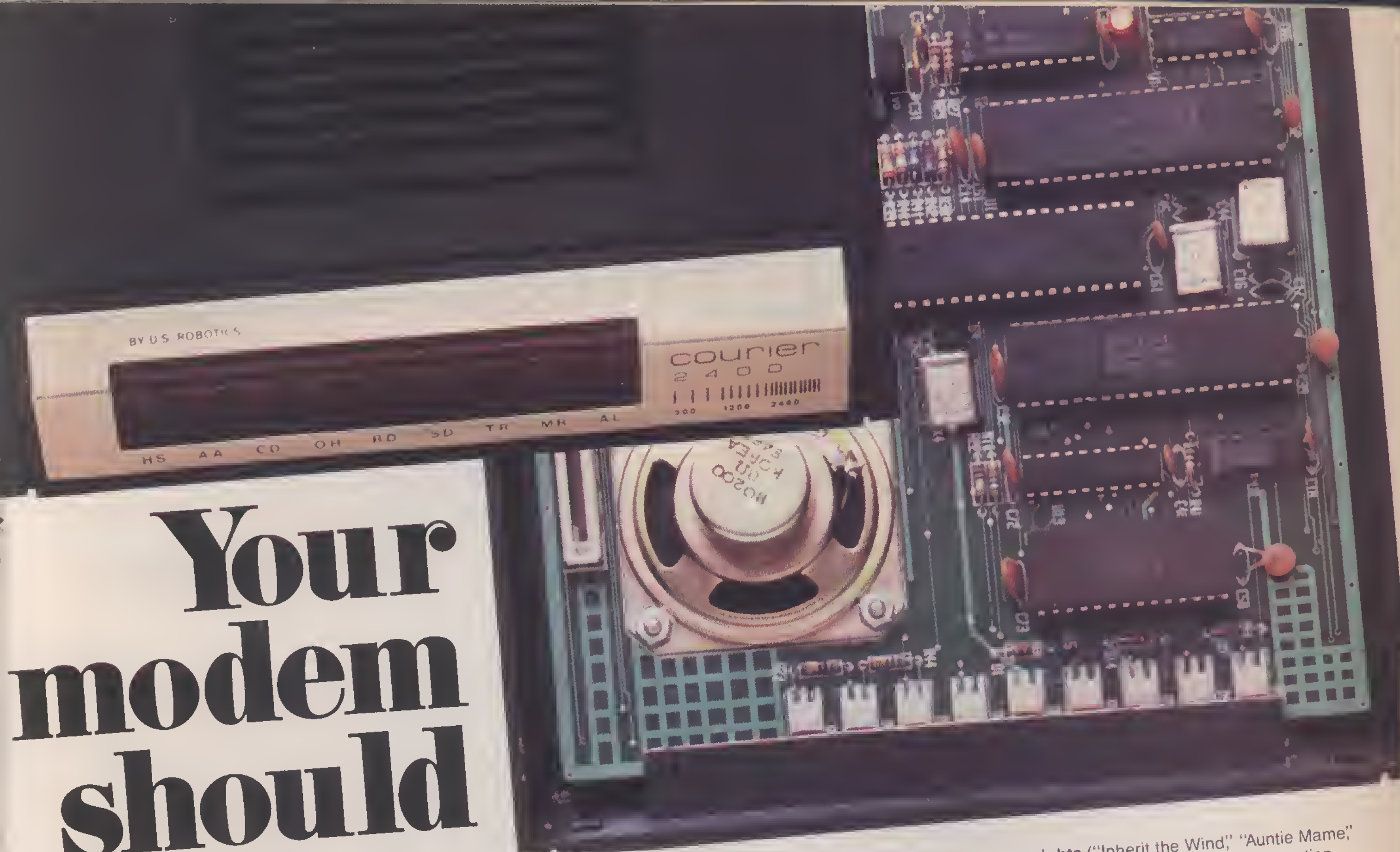
Future outlook. Will integrated CAD/CAM systems eventually result in true paperless engineering? That would be feasible today, as demonstrated by the GM/Boeing MAP/TOP exhibit at Autofact 85, but it would not necessarily be desirable. For many situations, hard copy will continue to be the most convenient, economical, and portable way of handling information. Integrated CAD-/CAM systems are most beneficial where hard copy is *not* convenient. In most cases, engineering data are better conveyed from design to production not with drawings but through the computer database.

In such integrated systems, designs can be readily modified and the required data transmitted quickly to appropriate areas. Needlessly redundant development efforts are eliminated. And individual departments can exchange information faster, removing the barriers that have traditionally separated design and manufacturing. Therefore, widespread use of such systems is expected well before the end of this century.

But while observers are optimistic about future prospects, they are also cautious about the obstacles to be overcome. "The growth in integration will undoubtedly be steady," says CDC's Christman, "but we have to keep in mind that successful implementation involves changes in company culture as well as computer systems." □

John K. Krouse, editor of Computer Aided Engineering, *writes frequently on* CAD/CAM.

For further information see **RESOURCES**, *p. 70.*



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CAN MACHINE TOOL

Foreign competition and factory automation pose tough challenges

The American machine tool industry is in the throes of a painful transformation. Formerly the unchallenged world leaders, U.S. machine tool companies have been steadily losing market share to powerful foreign competitors—particularly Japan. At the same time, manufacturing technology is changing so rapidly that machine tool builders must strain to stay abreast of their customers' growing demands for sophisticated manufacturing systems.

"As technology accelerates, the ante to stay in the business will go up," says analyst Eli Lustgarten, first vice-president of PaineWebber (New York). The archetypal American machine tool manufacturer used to be a small, family-run company, often carrying on the traditions of European craftsmen. But underpriced by Japanese imports and falling behind in technology, many small companies are going by the wayside or being absorbed by multinational manufacturers. "The large companies will get bigger at the expense of the small companies," says Lustgarten.

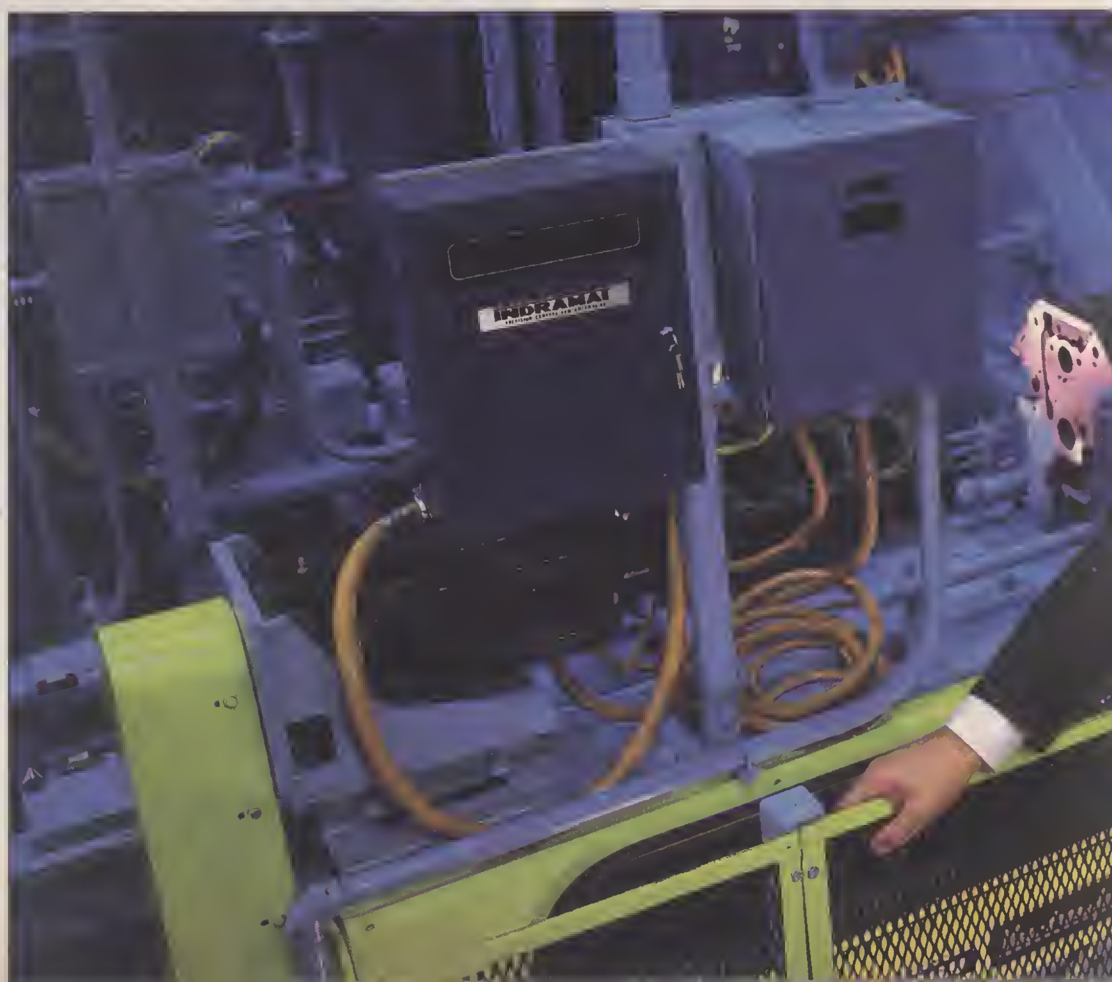
And consolidation isn't the only change rocking the business. New competitors from the computer and factory-automation industries are entering the machine tool sphere as well. As recently as five years ago, machine tools were considered stand-alone workstations that constituted the core of any manufacturing operation. But because of the shifting emphasis toward manufacturing systems, machine tools are being demoted and flexible automation systems—along with the software that ties them together—are being hailed as the new direction for the world's factories. Eventually, says Lustgarten, "the machine tool will become a piece of peripheral equipment for the computer."

The U.S. machine tool industry peaked in 1981, when—according to the National Machine Tool Builders' Association (McLean, Va.)—shipments totaled $5.1 billion. Since then the slide has been long and deep. The trough came at $1.8 billion in shipments in 1983. Although sales are rising, they're still less than half their '81 level. In fact, the real-dollar value of U.S. machine tool shipments hasn't been lower since 1949, reports the NMTBA.

by Jeffrey Zygmont

Meanwhile, imports are growing in strength and number. For example, Japan now accounts for about 75–80% of U.S. consumption of horizontal turning centers and machining centers—both basic metal-cutting tools that form the heart of many metal shops. Overall, imported tools in 1985 were valued at about $1.7 billion, approximately 45% of total U.S. consumption. As recently as 1980, imports had accounted for less than 25% of domestic machine tool trade.

Many industrial analysts warn that the growing reliance on foreign tools could one day cripple American manufacturing. "The machine tool industry is the cornerstone on which the entire manufacturing ability of the country rests," asserts Joseph Harrington, Jr., senior consultant at Arthur D. Little (ADL) in Cambridge, Mass. Machine tools are the factory implements that cut, form, and shape metal; they are the seminal machines that make the machines that make everything else. Thus, if foreign machine tool suppliers reserved their most advanced products for their home markets, or if



COMPANIES CUT IT?

shipments were cut off during times of political crisis, American manufacturing would suffer considerably.

An industry under siege. For all its importance to manufacturing, the machine tool industry is very small. All its members combined would rank only 161st on the Fortune 500 list. Outside a handful of larger companies, the business consists mostly of small manufacturers, many of them still family-owned. The 1982 Census of Manufacturers found that 90% of machine tool companies employed fewer than 100 workers.

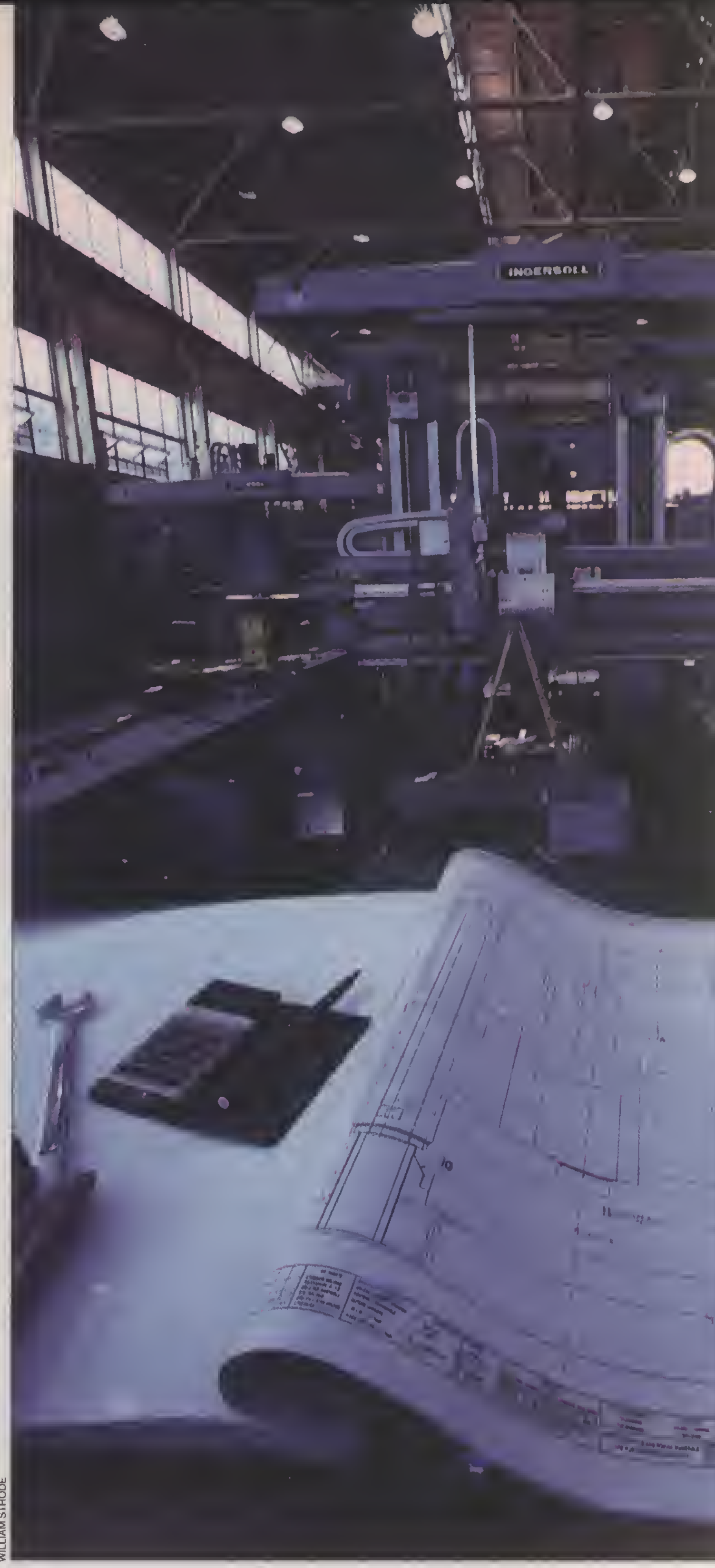
A Cincinnati Milacron milling machine grinds aluminum.

Unfortunately, their small size has prevented the majoritiy of machine tool makers from keeping up with the state of the art. They are generally undercapitalized and "not in a position to get into any deep experimental research," says Harrington.

What's worse, they are inevitably trapped in the most vulnerable part of a deeply cyclical market: Machine tool sales decline deeper than other products during a recession, and they are the last to recover. Although machine tool customers maintain some output during down cycles, they do not buy new machines when capacity is idle. So even demand for replacement machines slows to a trickle. When prosperity returns, manufacturers typically delay new equipment purchases until they have a healthy log of new orders. Thus recovery in the machine tool sector lags a general economic recovery.

The industry was so debilitated by the last recession—plagued both by abysmal markets and by import penetration—that the NMTBA has filed a "national security" petition asking the President to limit machine tool imports to 17.5% of U.S. consumption

"We have concentrated very heavily on R&D," says Cross & Trecker CEO Richard T. Lindgren, shown with an automated engine-block machining center made for Chrysler.



WILLIAM STRODE

for five years. "The objective is to assure that there will be adequate domestic capacity and supply to meet any sudden surge or a substantial mobilization," explains Kim McCarthy, legislative analyst for the trade group. A ruling on the petition is expected early this year, although observers predict it will be denied, as was a similar request initiated by Houdaille Industries (Fort Lauderdale, Fla.) two years ago.

American machine tool builders, therefore, will likely continue to be on their own in vying with overseas firms for share of the U.S. market, the largest in the free world. One strategy, according to many in the industry, is to concede defeat in certain segments of the market and concentrate on others where American machine tool makers still have the edge.

"Specialization is one of the keys," says Richard T. Lindgren, president and chief executive officer of Cross & Trecker (Bloomfield Hills, Mich.). "It's futile to commit resources where there is no chance to make money." Specifically, many U.S. manufacturers are abandoning the low-end commodity markets, concentrating instead on special-purpose machines. "The 'quality segment' belongs to U.S. manufacturers," says Lindgren, "while the 'price segment' resides with the Japanese." Robert Pierfelice, president of the Cross & Trecker subsidiary Cross & Co. (Fraser, Mich.), agrees. "We don't have a standard line," he says. "Every product we make is custom designed."

While the elimination of low-cost, standardized tool lines has helped to keep machine tool companies afloat, it has also scaled down their operations. "We've already phased out dozens of basic machines, which, because of imports, no longer have the potential for good profitability," reports Daniel J. Meyer, vice-president of Cincinnati Milacron. "As a result of this consolidation, we've cut our machine tool workforce worldwide nearly 40% in the last five years."

U.S. companies are using imports to compensate for these capacity reductions. "Half of our members import something for sale," says Joe T. Franklin, statistical director of NMTBA. Beginning this year, for example, Cincinnati Milacron will import lathes from Japan's Hitachi Seiki and install its own computerized numerical control (CNC) devices before selling them in the United States. Similarly, Cross & Trecker recently formed a 50/50 joint venture with Murata Machinery of Japan—called Murata, Warner & Swasey—which now supplies turning centers and turret punch centers for the U.S. Meanwhile, Cross & Trecker has begun a joint manufacturing venture in India that may export to the U.S. And the company is studying the feasibility of a venture in Taiwan to underprice even the Japanese imports.

"We had not really done much offshore," explains Lindgren. "But when we saw the price segment of the market developing, we had to find ways to modify the cost of our machines." Rather than downgrading existing Cross & Trecker designs, the company went shopping for foreign products.

Similarly, Acme-Cleveland's Hillyer division (Mountainside, N.J.), a maker of vertical machining centers, hopes to break from its traditional markets in automotive and aerospace manufacturing. Anticipating an operating loss this year after breaking even in 1985, Hillyer is cultivating more stable clients among medical equipment manufacturers.

The move by Hillyer mirrors similar efforts by its parent company to "transform ourselves away from many of our traditional markets," says Richard B. Ainsworth, Acme-Cleveland vice-president and treasurer. Once listed among the top machine tool suppliers, Acme-Cleveland is diversifying into the less cyclical telecommunications and electronics markets.

At the same time, the company is augmenting its machine tool expertise with electronics and software development. Acme is readying CNC add-on units to enhance its National Acme line of mechanically operated metal-cutting tools. It also hopes to tap the aftermarket by retrofitting its computer controls to some of the 20,000 machines it has supplied around the world.

Integrated systems. Acme-Cleveland's recent interest in CNC reflects the U.S. machine tool industry's growing emphasis on automation control and software development, but it may be too little, too late. "Software is going to be the driving force of the industry," says Harry Mathews, manager of ADL's manufacturing engineering and automation unit. As machine tools give up their autonomy to become parts of manufacturing systems, the "system integrators"—

ROMAN SAPECKI

Top: Tool makers must differentiate their products through advanced technology, says Schuler Industries' Richard D. Besser. Above: To sell machinery for making aircraft-wheel parts to Parker/Cleveland, Cross & Trecker attached Fanuc material-handling robots (yellow and red) to its numerically controlled turning machines. Left: GM recently ordered $50 million worth of custom machining centers from Ingersoll Milling Machine; they are expected to shrink the time needed to produce dies for body parts.

suppliers of the coordinating and controlling software—are becoming the powers of the machine tool industry. These companies, generally from outside the traditional machine tool community, are capitalizing on their expertise in automation control to assemble the systems from diverse components gathered from a broad base of suppliers.

For example, General Electric's Factory Automation Products Division (Charlottesville, Va.) supplies the control hardware and software for integrating separate machines into a manufacturing system. In an arrangement called distributed numerical control (DNC), a central computer downloads instructions to the various CNC machines in the manufacturing cell and acts on their feedback to coordinate operations.

The most sophisticated manifestations of DNC—flexible manufacturing systems—are capable of making a broad range of different products simply by changing instructions. For instance, a flexible system at Deere & Co.'s tractor component plant in Waterloo, Ia., can make eight different transmission housings in mixed batches.

So far, the use of flexible manufacturing systems is limited. Only 200 are in operation worldwide—50 in Japan, 47 in the United States, and the rest mostly in Western Europe—according to PaineWebber's Lustgarten. But most observers agree that this is the manufacturing direction of the future. The Yankee Group, a Boston market research firm, predicts that such systems will grow 40% by 1990.

The bad news for the average machine tool maker is that only top companies like Cincinnati Milacron, Cross & Trecker, Giddings & Lewis (Fond du Lac, Wis.), and ExCello (Troy, Mich.) can afford the R&D investment needed to provide integrated manufacturing systems. Most machine tool manufacturers will have to adapt their machines to fit into overall systems that are not their own, and firms that lack the wherewithal or the sophistication to do so could easily find themselves left out in the cold.

And the biggest threat is. . . . So far, the threat of takeover of machine tool companies by computer and automation firms hasn't materialized, although ADL's Mathews predicts that consolidation by system integrators will increase over the next five years. "There are just too many players and not enough sales," he says.

But even at the upper end of the market, the main problem for U.S. machine tool makers may be their old adversaries at the low end: the Japanese. Many American companies contend that Japanese competitors won the low-price, standardized machine tool market on price alone; others say this is wishful thinking. "The machine tool industry has to wake up to the challenge that the Japanese have presented them," says one automation control supplier. "When you go through product evaluation and analysis, you find that not only are the Japanese tools cheaper, they're better."

The Japanese triumphed by fitting their machine tools to the needs of industry, says Richard D. Besser, president and CEO of the press maker Schuler (Columbus, Ohio). "They took a look at the market and found out what the market wanted." Meanwhile, manufacturers in the United States have *not* been market-driven. Instead of surveying their customers to learn current and future machine needs, says Besser, they stuck complacently to traditional equipment lines.

Until now, U.S. companies in the high end of the market have largely been insulated from foreign competition. "It's very hard to do sophisticated, highly technical work when you're 6000 miles away," says Besser. The constant liaison between engineer and customer is just not possible.

But anyone who knows the Japanese track record in other global markets also knows that distance may not prove much of a constraint. ADL's Mathews points out that many Japanese machine tool companies are setting up U.S. operations to support the sale and servicing of integrated systems. Machinery maker Komatsu, for example, has established Komatsu America Industries to market its products, and machine tool maker Yamazaki recently set up a manufacturing subsidiary, Mazak, in Florence, Ky.

"The United States is now becoming a truly international market," warns Mathews. "Unless U.S. machine tool companies pay attention, the Japanese are going to beat them." □

Jeffrey Zygmont is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 70.*

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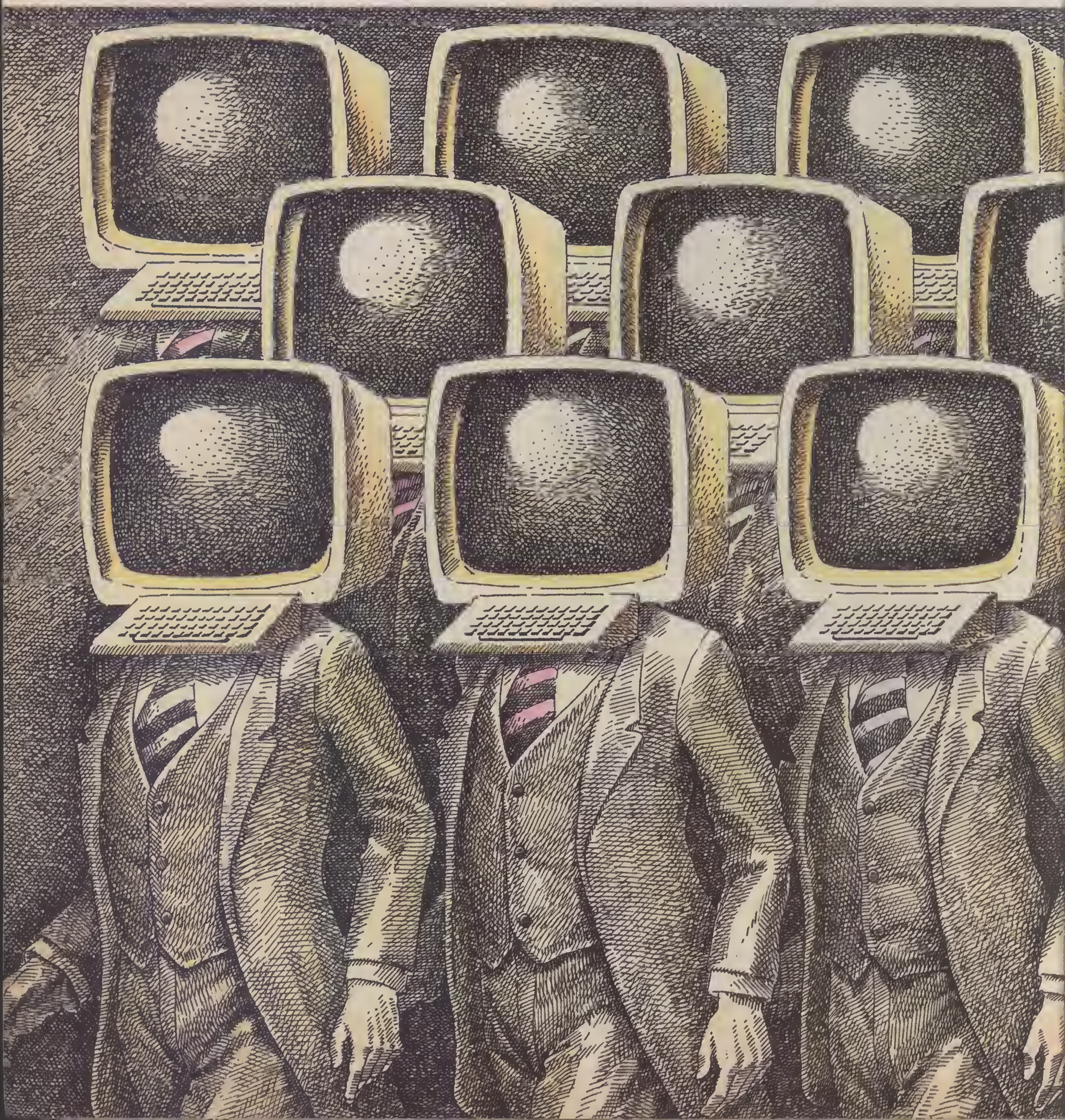

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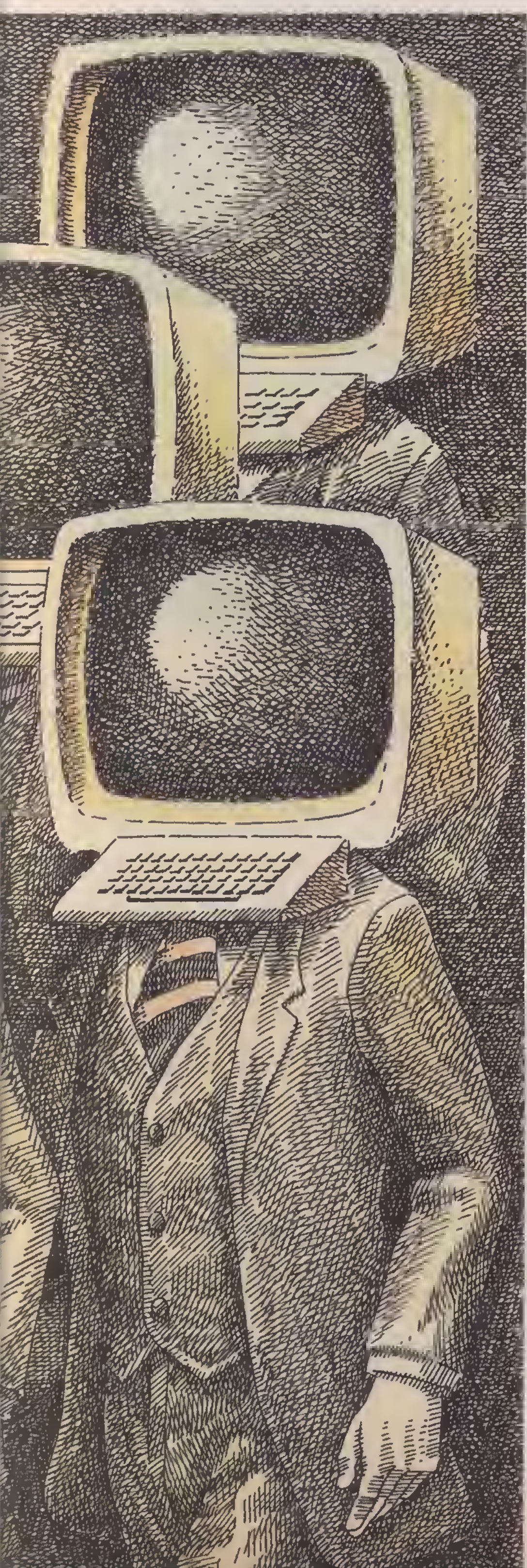

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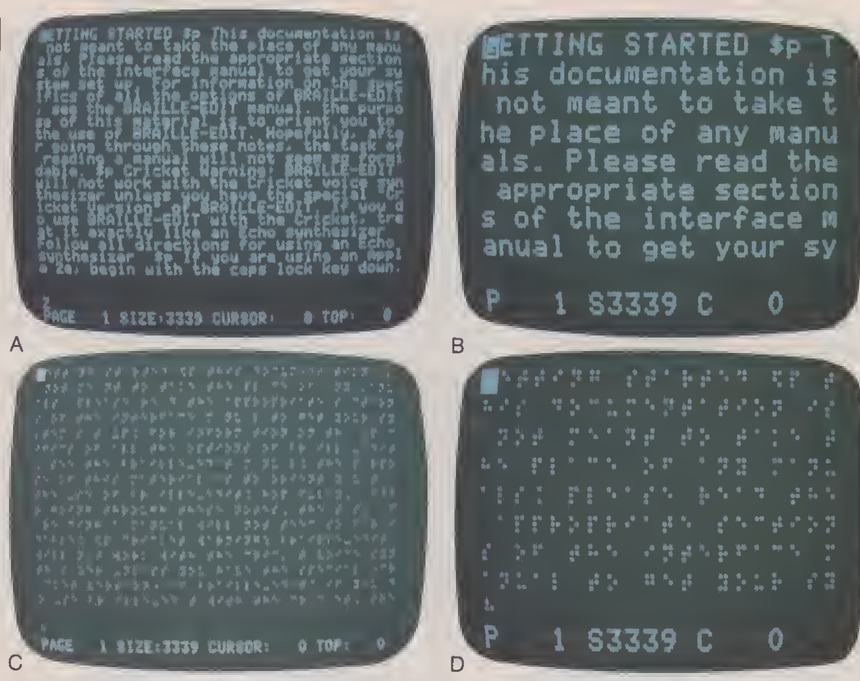
OPENING THE WORKPLACE TO THE DISABLED

Products such as talking software and braille printers provide the key



Raised Dot Computing's Braille-Edit-Express program can display regular-size type (A) or enlarged type (B) for partially sighted operators. Alternatively, sighted transcribers can type ordinary English on a standard keyboard and the program can display the input as normal-size braille (C) or enlarged braille (D), which can then be output on a braille printer.

PHILIP ROUNSEVILLE

Computers, especially microcomputers, have brought sweeping changes to American business. But their greatest impact may be felt by a group of workers often overlooked by the community at large: the disabled. Custom-designed devices as well as new products designed to work with standard computers, are now allowing disabled employees to communicate with corporate computer systems through voice, large print, or braille.

For more than a decade, there have been legal incentives to hire the disabled, as well as social and economic advantages. For example, Section 504 of the Rehabilitation Act of 1973—a sweeping federal antidiscrimination regulation—requires that job sites, schools, and the buildings of most other institutions be accessible to all disabled persons. Beyond the letter of the law, its spirit is that having provided accessibility, employers must not isolate handicapped employees from other workers.

Among the adaptive aids that can ease this integration process are speech synthesizers, braille printers, voice recognizers, input systems for the motor disabled, large-print screens and printers, and talking software. Word processors, databases, spreadsheets, telecommunications systems, and programming languages can be configured to accept voice input or to provide synthesized speech. And such products are growing increasingly inexpensive: Although talking word-processing systems for IBM and Apple personal computers can cost several thousand dollars, most cost no more than $400.

Vendors of computer products for the disabled fall into two broad categories: companies, often very small, that make products specifically for narrow sectors of the handicapped market, and companies that sell general-market hardware and software that happen to also fit the needs of people with certain disabilities. "Quite often, producers of general-purpose products aren't in the least aware of what they've got in terms of the products' applicability to people with special needs," says Budd Hagen, editor of *Closing the Gap* (Henderson, Minn.), a bimonthly newspaper that covers computer technology for the disabled. For instance, Street Electronics (Carpenteria, Cal.) marketed a speech synthesizer for Apple PCs for several years before recognizing that the product could be an aid to the handicapped. Now about 50% of the product's sales are in special education and rehabilitation markets, says Hagen.

Speech synthesis gives microcomputers the power to verbalize the contents of most off-the-shelf software. For instance, a blind operator working with a word-processing program might hear the phrase "edit an old document" when the cursor is placed on that menu item. Once in the document, the computer will "speak" whatever words are on the screen, as well as any changes typed in by the operator.

The programs that make computers talk—text-to-speech algorithms—convert standard English into basic word sounds by means of letter-to-sound rules. These algorithms contain about 500 rules, and are typically about 95% accurate in turning most displayed text into spoken language. The algorithms can sound out words, one letter at a time, or they can speak whole words and their abbreviations.

Some text-to-speech software is able to take advantage of existing computer hardware to produce the actual word sounds. The SmoothTalker program from First Byte (Long Beach, Cal.), for example, uses the speaker built into every Apple Macintosh computer to produce speech. Most often, however, the user must insert speech synthesizer

by Joseph J. Lazzaro

boards or attach a stand-alone speech unit to the computer. Such hardware can be fairly inexpensive—the Echo-Plus speech synthesizer from Street Electronics costs about $150. More sophisticated devices can cost considerably more. Digital Equipment's DecTalk speech synthesizer, a stand-alone unit that can attach to any computer and speak its screen contents, is priced at about $4000. (Non-profit organizations can buy the product for $1600 through a DecTalk grant program.)

There are numerous application packages for personal computers designed specifically for operation with speech synthesizers. The Braille-Edit-Express program from Raised Dot Computing (Madison, Wis.), for example, is a talking word processor that runs on Apple IIe and IIc computers. In addition to generating voice output, the $400 program can produce large-print and braille output, and can link the Apple with other micro or mainframe computers. Using Braille-Edit-Express, a blind employee can type text into an Apple computer, use speech output for verification, and pass the text to a sighted employee to be read on any standard monitor screen. The program will also read and write files compatible with most other standard word-processing packages, giving the blind employee access to these systems.

The Word-Talk program from Computer Aids (Fort Wayne, Ind.), another talking word-processing system, comes in both an Apple II version ($200) and an IBM PC version ($300). Unlike Braille-Edit-Express, which displays special codes for functions such as centering a line, Word-Talk is a screen-oriented editor that actually displays the formatted text as it will appear when output. The program can also link an Apple II and an IBM PC for two-way text file transfers, making it easy to share information in multiple disk formats. Word-Talk supports nearly every voice synthesizer currently on the market, in addition to most dot matrix and letter-quality printers.

Another class of products, called talking terminal programs, lets stand-alone microcomputers link with remote mainframes or other computers. With these programs, everything typed locally for transmission to the host, as well as everything sent from the host to the user, is both voiced and displayed on the video screen. Talking Transend from Computer Aids, for example, is an Apple-based talking telecommunications program with the ability to interface with most computers. The program, which costs about $200, can also save all two-way interactions on floppy disks for editing at the operator's convenience.

Talking Termexec from Quinsept Software (Arlington, Mass.) is another Apple-compatible talking terminal program. Priced at $95, Talking Termexec can send and receive data files with full speech output of all screen text, and can be used to transmit computer programs error-free. Programs such as Talking Transend and Talking Termexec can also be used to query large information utilities such as The Source and Compuserve.

Talking software programs such as Braille-Edit-Express and Talking Transend were designed specifically for blind users. Another approach involves speech drivers—programs to voice the popular software applications sold to sighted users. These drivers are often referred to as "screen readers," but a more accurate name is "talking operating systems." A user simply loads such a system into the computer and then runs standard packages such as WordStar or Lotus 1-2-3 on top of it.

While such talking operating systems give blind operators access to most commercial software (the programs are unable to voice graphics packages), they may not work as smoothly as the packages designed specifically for voice output. For example, some speech drivers might voice the entire screen every time a new character is typed on a standard word-processing package. (By contrast, a product like Braille-Edit-Express would speak just the new character.) To prevent the constant voicing of the entire screen, an operator might choose to turn off the voice feature while editing, and turn it back on to hear the completed changes. The fact that the talking operating systems give blind users access to most commercial software more than makes up for such shortcomings.

An example of a talking operating system is the Enhanced PC Talking Program sold by Computer Conversations (Columbus, Ohio) for use on IBM's micros and more than 50 compatibles. The program can make up to 95% of the IBM software library talk without modification, says president and chief programmer Ron Hutchinson. It can also identify color, flashing, and inverse video text. The program costs $500 for individuals and $700 for institutions.

Other talking operating systems—such as Screen-Talk from Computer Aids and Freedom-1, sold by Interface Systems International (Portland, Ore.)—work with most word processors, databases, spreadsheets, and telecommunications packages. These products are state-of-the-art because they take screen-based software and turn it into speech-based software without rewriting a single line of code. The talking operating systems sit in the background, just like a disk operating system, until they are called upon to accomplish their verbal tasks.

Quite simply, talking operating systems enable blind operators to function very much like their sighted counterparts, using the same application software. "I use an IBM PC/XT with the Enhanced PC Talking Program to do financial forecasting on our mainframe computer," says Albert Gayzagian, director of corporate analysis at John Hancock Financial Services (Boston). "The talking software lets me accomplish my job as if I weren't blind."

Another technology that has been adapted for use by the blind is optical character recognition (OCR). Such systems give computers the ability to read printed words, and work as peripherals to standard computers or form the basis of specially designed machines for the blind. The most famous example is the Kurzweil Reading Machine (KRM), marketed by Kurzweil Computer Products (Cambridge, Mass.).

The KRM merges the technologies of OCR, microcomputers, and voice synthesis, and can recognize almost any typeface. Once scanned, the text can be spoken by the machine's voice synthesizer at up to 250 words per minute. Alternatively, machine-readable text can be translated into standard print, large print, or braille, or can be sent to other computer systems. All this power comes at a price: The KRM retails for $29,800. OCR peripheral systems without the KRM's extras are considerably less expensive, but still cost $2000–$3000 in most cases.

Just as speech synthesis and OCR are critical technologies for assisting the sight-impaired, speech recognition is the key technology for the motor-impaired. Speech recognition systems from companies such as Votan (Fremont, Cal.) and Kurzweil Applied In-

telligence (Waltham, Mass.) give microcomputers the power to respond to spoken commands, and have recently begun to make significant inroads into the business computing marketplace. Votan markets voice recognition devices for $2000–$3000. Kurzweil recently introduced its 1000-word vocabulary, Kurzweil Voice System 3000, and plans to market a 15,000-word vocabulary, Kurzweil Voice Writer, sometime this year (HIGH TECHNOLOGY, Jan. 1986, p. 58). These devices are aimed squarely at general usage in businesses, but they also offer increased computer access to the motor-disabled.

Because of falling prices, it is increasingly cost-effective to add voice recognition equipment to an existing microcomputer, thereby enabling virtually any standard application program to be operated by voice command and control. In fact, current voice recognition software is flexible enough to be trained to almost any voice, even one that is garbled by limited muscle control. Most voice recognition software comprises sets of routines that break down spoken sounds into computer code commands understandable to the host microcomputer. The host "thinks" the information is being typed, but commands are really coming from a microphone, not a keyboard.

The immediate future of adaptive computer systems appears bright as the technologies become more reliable and less expensive. With prices now often running in hundreds of dollars rather than thousands, consumers are increasingly able to afford these devices.

The ramifications of these systems are great, says Hagen at *Closing the Gap.* "We've discovered that handicapped people, no matter how severe their disabilities, can gain complete and total control over a computer system and use it for whatever it can normally do. The first step is meeting an individual's special needs, so he can then go about meeting his normal needs—the same ones that everyone else has." □

Joseph J. Lazzaro, a freelance writer and computer consultant in Revere, Mass., specializes in speech input and output systems.

In its April/May 1985 issue, Closing the Gap *published a directory of hardware, software, organizations, and periodicals that relate to computers for the disabled. The single issue, at $7.95, is available from PO Box 68, Henderson, MN 56044.*

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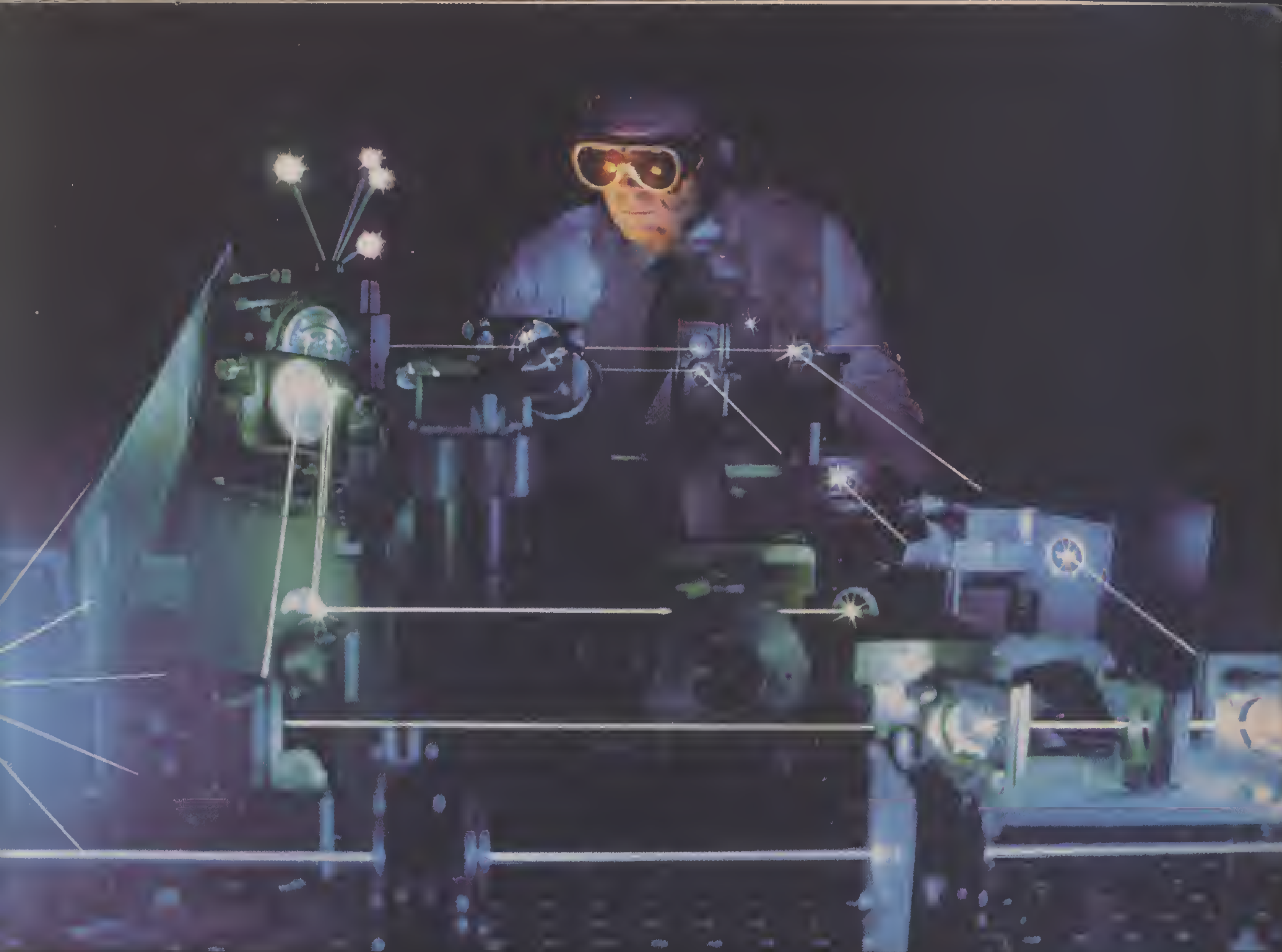


7.

COMPUTERIZING CARS

Increased digital control will let autos change performance to suit the driver

In the modern automobile, tiny microprocessors already control fuel flow, ignition timing, digital displays, and sophisticated audio systems. And further computerization is rapidly proceeding.

"If you consider what cars will be like in the year 2000, we're probably only about 10% of the way there," says Joseph F. Ziomek, engineering director of the Advance Technology Center of TRW's Transportation Electronics Group (Farmington Hills, Mich.). "By the end of this decade," claims Ziomek, "microprocessors will make automobiles so adaptable that a touch of a button will change the car's character to suit its driver." He calls the concept "the chameleon car—it will change everything but color."

Less than a decade ago, when basic computerized engine controls were first introduced, U.S. carmakers spent an average of only $200 per car on electronic equipment. By 1984, despite declining prices of many computer components, electronic content was up to nearly $600 per car, estimates Jerome G. Rivard, chief engineer at Ford's Electrical and Electronics Division. Auto electronics will reach almost $900 in value by 1990, says Rivard, who concurs with a University of Michigan study that places average electronics value at $1350 by 1992. By then, the chameleon car should be rolling down the nation's highways with enough computer power under the hood to run a fair-sized business.

by Jeffrey Zygmont

With adaptive computer controls in the car of the 1990s, steering may be set easy for fingertip parking or tightened for sports-car handling. Suspensions may be instantly modified for smooth boulevards or rough backcountry roads. Engine performance may be sporty or restrained. Seats may cradle or bolster. Curb height may be high for easy entry or low for speed. "Microprocessors will allow a sedan to be a sports car on demand," says Ziomek.

KEN CONDON

A rudimentary component of the chameleon car might be TRW's memory-seat module, now available in General Motors' luxury cars. An 8-bit Motorola 6805 microprocessor controls the electric motors that drive the six-way power seat. Two seat configurations may be programmed and automatically recalled by a switch mounted near the seat controls. TRW expects to extend the system to preprogram radio tuning and climate control settings. Thus, two or more drivers—or the same driver in different moods—could change the cabin environment with a single button.

Beyond cabin features, adaptability will soon be extended to critical automobile functions such as power transmission, steering, suspension, and braking. The 1986 Japanese Mitsubishi Galant and Mazda RX-7 cars already feature dashboard selection of either a firm, sporty ride or a softer, highway ride. Both cars use alterable suspensions with microprocessors to control shock-absorber valving; under development are systems that will also monitor vehicle speed, automatically firming up shocks for better handling at higher speeds. Currently available in Japan as an option on the Nissan Bluebird luxury sedan is a system that automatically adjusts suspension in response to road roughness. Microwave transceivers mounted ahead of the front wheels sense road undulations, feeding the data to a computer that alters suspension for a harder or softer ride.

In the U.S., the 1986 Lincoln Continental Mark VII has a computer-controlled suspension with inflatable rubber air bags replacing conventional steel springs. Position sensors at the two front wheels and rear axle feed a microprocessor that controls a miniature air compressor. The computer automatically adjusts bag inflation to

compensate for changing load, keeping the car level during accelerations and decelerations, as well as during turns. Says Ford's Rivard, "Our next move in suspension control may be to alter shock-absorber valve rates and air-bag inflation pressure to vary handling characteristics."

While few cars today approach the sophistication of the Lincoln, virtually every gasoline-powered car sold in America relies on microprocessor engine control. The transition from mechanical control was abrupt, driven by pressure from Washington. "Without computer control," explains engineer Jonas Bereisa of GM's Delco Electronics Division, "automobile engines would have become hopelessly sluggish under the weight of fuel economy and emission regulations." The first engine computer appeared in 1977, controlling spark timing on the Oldsmobile Toronado. Today GM is the world's largest consumer of microcomputer chips.

Perhaps more significant than engine controls are the new chassis systems that use computers to improve a car's handling. In a computerized antilock braking system made by Robert Bosch (Stuttgart, West Germany) and available on several U.S. and European luxury cars, wheel-speed sensors measure deceleration during rapid stops. If the computer detects that a wheel is stopping too quickly—meaning it may lock and send the car into a skid—the microprocessor automatically reduces hydraulic brake pressure in the affected wheel until the danger of skid is averted. The result is straight stops even on icy pavement. In addition, Bosch is developing anti-spin systems to detect wheel spin during rapid acceleration. A signal is sent to the engine control computer, which then eases acceleration to maintain good traction. Thus, the vehicle takes off only as quickly as is feasible—no matter how hard the driver stomps on the accelerator.

Steering, too, is being brought under microprocessor control. Electronic steering systems, which replace the mechanical hydraulic pump of conventional power-steering systems with an electric motor that turns on and off on demand, are under development by TRW, GM's Saginaw Steering Gear Division, and the Bendix Division of Allied Automotive (Southfield, Mich.). Electronic steering improves fuel economy, since the assist motor loads the engine only when effort is needed to turn the steering wheel. By contrast, the hydraulic pump that drives conventional power steering is always scavenging power from the engine, even when the steering wheel is stationary.

"By the end of this decade, microprocessors will make automobiles so adaptable that a touch of a button will change the car's character to suit its driver."

Computer-aided four-wheel steering, now in its infancy in Japan, will radically increase automotive maneuverability. Mazda has taken a small step in that direction with a system in the new RX-7 sports car that provides a slight steering assist from the rear wheels at speeds above 15 mph. The rear wheels are mounted on a subframe, which is isolated from the car body by rubber bushings at the frame's mounting joints. On the command of a control computer, small hydraulic actuators push the frame, rotating the wheels slightly in the direction of the turn. Since frame movement is restricted by the rubber bushings, the wheels rotate only half a degree. But the maker claims that this is enough to make the vehicle glide more smoothly into lane changes.

TRW's engineers predict that four-wheel steering will be further refined to respond differently according to speed. At high speeds, only slight rear steering movements will be allowed. However, at low speeds, greater steering rotation will enhance maneuverability. "For parking, the rear wheels may even move in opposition to the front wheels, so the car nearly pivots in place," says Ziomek. "Since the rear wheels are not directly connected to the steering wheel, with electronic control you can move them any way you want."

With separate computers for engines, transmissions, steering, and displays, auto engineers are now beginning to consider the computational needs of the car as a whole. "Chassis computers are just starting to see some evolution," says Leonard J. Groszek, technical planning manager of Ford's Electronics Division. "Today our suspension and braking are standalone boxes. In time, we will centralize them into one chassis computer for more sophisticated control. In an antilock braking situation, for example, we might want to simultaneously stiffen up the suspension system and the variable-effort steering as well."

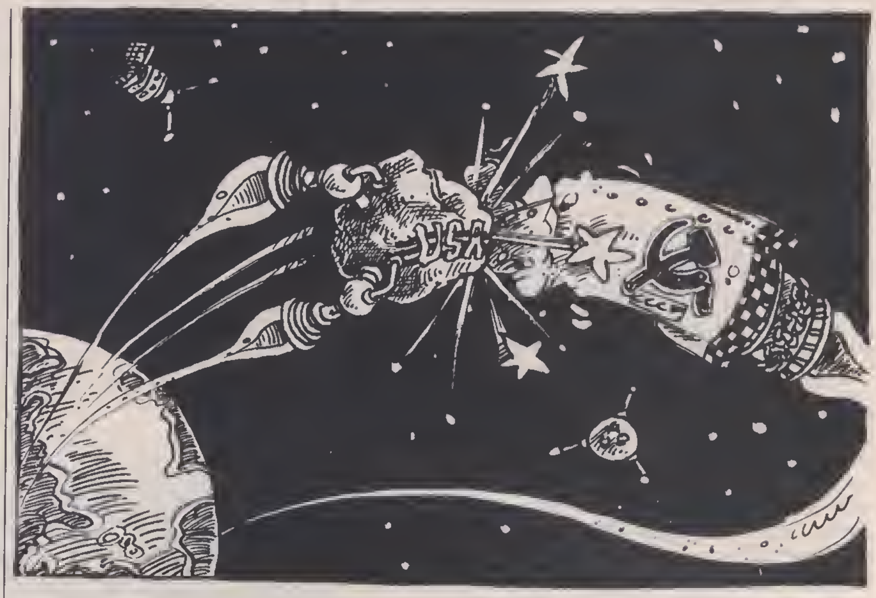
This consolidation of discrete control functions into a single computer is also evolving in cabin microprocessors, as evidenced by the Buick Riviera's Graphic Control Center (HIGH TECHNOLOGY, Nov. 1985, p. 10), which regulates virtually every non-engine function inside the car. Groszek predicts that in 10 years, three primary automotive computers—dedicated to engine, chassis, and cabin control—will share data and communicate via a single, multiplexed communication link. "The system will be so sophisticated," he says, "that if one of the computers has a problem, the other two will take over until the car owner has time to have it fixed."

Sophistication might not stop there, speculates Groszek. "Picture a car with 'eyes' that would automatically take control of your car and swerve to avoid an object." Such systems are possible, he says, but must await higher-speed and larger-capacity parallel processors. □

Jeffrey Zygmont is a senior editor of HIGH TECHNOLOGY.

STOPPING MISSILES WITH A WHAM, NOT A ZAP

Proposed kinetic-energy weapons range from magnetic guns to "smart rocks"



JON MCINTOSH

For 30 years, the Pentagon has been looking for ways to destroy ballistic missiles in flight. It has considered antiballistic missiles (ABMs) equipped with nuclear warheads, and, more recently, laser and particle beams. But within the Strategic Defense Initiative ("Star Wars") program, there is widespread concern that nuclear-tipped ABMs may be too destructive, and beam weapons not destructive enough. As a result, a less exotic but perhaps more workable approach is coming to the fore: kinetic-energy weapons.

Launched from a rocket or an electromagnetic gun, these self-guided weapons would home in on and collide with a ballistic missile at high speeds—typically at least 5 kilometers per second more (about 10,000 miles per hour). At such speeds, the energy of impact (kinetic energy) would be sufficient to destroy a missile. To work, a kinetic-energy weapon must physically strike its target—a task that is frequently compared to hitting one bullet with another in midflight. But defense officials are confident that the required accuracy is within the reach of current guidance technology. Indeed, so confident are they that the Strategic Defense Initiative (SDI) Organization is requesting $1.24 billion for development of kinetic-energy weapons in 1987, compared with $1.20 billion for laser and particle beams.

Such enormous outlays rankle SDI's critics. They maintain that development of a truly effective defense against nuclear attack is highly unlikely because leakage of even a small fraction of the thousands of warheads thrown our way during a full-scale attack could virtually destroy the country. The Soviet Union could thus overpower any "shield" by building more and more offensive weapons—hardly in the spirit of arms control.

by T.A. Heppenheimer

Administration officials obviously have a more optimistic outlook; they envision a gauntlet-like system capable of attacking a missile anywhere along its flight path. SDI planners divide the flight path into four phases: the boost phase when the rocket leaves the launching pad, the post-boost phase when it deploys its warheads and decoys, the midcourse phase, and the terminal phase when the warheads reenter the atmosphere and fall on their targets.

Destroying a missile during the boost phase offers the greatest rewards. All its warheads are in a single package, where they can be destroyed at one blow. Moreover, its rockets produce a bright exhaust that would be readily visible to battle stations orbiting overhead.

This opportunity will be fleeting, however. Present missiles fire for little more than a minute during launch, and future Soviet rockets may flame out even sooner. To destroy missiles in the boost phase, therefore, SDI officials are looking to railguns—electromagnetic catapults that can accelerate projectiles to more than 25 kilometers per second. These weapons would be stationed in orbit roughly 300 kilometers above Soviet missile fields.

A railgun consists of two parallel rails, with a moving bridge or armature between them that carries a projectile. Electric current surges up one rail, across the bridge, and back down the other rail, producing a powerful magnetic field along the rails. As the current crosses the bridge, it interacts with the magnetic field to produce a force that pushes the bridge down the rails with very high acceleration, thus launching the projectile. This same force pushes the rails apart; hence they must be strongly braced, enclosed within a gun barrel. Among the companies that have prepared design concepts for railguns are Aerojet Techsystems (Sacramento), LTV Aerospace (Dallas), Westinghouse (Pittsburgh), and GA Technologies (San Diego).

The required flows of current would come from specialized generators whose development is already well advanced. The homopolar generator, for example, derives electricity by spinning a flywheel at high speed within a magnetic field. On its inner and outer rims are brushes that switch the flywheel into the electric circuit. When the flywheel touches these brushes, it generates a very short but intense power pulse, suitable for a railgun. Homopolars are under active development at

Westinghouse and the University of Texas Center for Electromechanics in Austin. Parker Kinetics, an offshoot of that center, sells them commercially for $300,000.

To date, the emphasis has been on building small-bore experimental railguns, firing projectiles the size of bullets. The barrels are only a few meters in length, thus limiting the bullets' speeds. At Picatinny Arsenal in Dover, N.J., the Army's center for advanced guns, Westinghouse has installed a railgun whose projectiles have reached 4.2 kilometers per second (km/s). A gun built by LTV Aerospace has attained speeds of 8.6 km/s, but with lighter bullets.

Today's experimental railguns suffer from a constraint that would render them virtually useless in an operational defense system: They cannot fire multiple shots in rapid succession. The reason is that present electrical switches cannot survive the million or more amperes of current that must course through them to fire the gun. The Westinghouse gun at Picatinny, for example, must be rebuilt with a new switch after each shot.

Railgun developers working to overcome this problem have achieved limited success. In August 1984, a GA Technologies gun fired a burst of five shots in a test at Eglin Air Force Base in Florida. It relied on a switch built by IAP Associates (Dayton). "The switch burned out its brushes, but it worked," says Leo Holland, a railgun program manager at GA.

GA Technologies has devised a railgun that employs the projectile itself as a switch. On entering the barrel, the projectile completes the circuit and fires the gun automatically. The problem is that the current persists after the shot, draining the power supply and threatening to melt the end of the gun. "We're trying to figure out how to interrupt the current," says Holland.

Because of such problems, railguns clearly have a long way to go before they can be considered suitable for deployment in a ballistic missile defense system. Even then they would have to compete against laser and particle beams. These directed-energy weapons would offer a significant advantage over railguns for boost-phase kill, admits Gen. Malcolm O'Neill, manager of SDI's kinetic-energy weapons program. "We all know photons will arrive in a timely fashion," says O'Neill—after all, they travel at the speed of light, which is about 10,000 times faster than a railgun projectile. Still, by the time these beams reach the missile, they may lack sufficient punch because of atmospheric attenuation. Moreover, their effect could be blunted by such countermeasures as rotating the missile or the use of reflective coatings.

Immediately following the boost phase, the missile's warhead carrier, or bus, separates from the booster. The bus deploys its warheads and decoys, maneuvering as it does so. Because it uses only small rockets, the bus is more difficult to track than the booster. Moreover, each warhead or decoy it releases represents an additional target that must be tracked and, if possible, destroyed.

Smart rocks will have to "approach genius intelligence" to hit warheads in space.

When its cargo has been released, the missile enters the midcourse phase. It is now in the form of a cloud of nuclear warheads accompanied by a great many "penetration aids"—decoys, balloons enclosing bombs or other decoys, empty balloons, radar-reflecting metallic strips, and infrared-emitting aerosols. All these must be tracked and distinguished from the warheads that are to be destroyed. Lasting as long as 20 minutes, this midcourse phase affords more time to track and discriminate.

To destroy warheads in midcourse, SDI is developing "smart rocks," volleyball-size missiles weighing about 5 kilograms. A smart rock would ride into battle atop a rocket some 2 meters long moving at 5 kilometers per second. Once launched, the smart rock's own rockets would propel it to its target using self-contained guidance and tracking sensors. An SDI concept called Porcupine envisions an array of orbiting battle stations, each armed with 50 rocket-propelled smart rocks.

Rocketdyne (Canoga Park, Cal.) and LTV Aerospace are developing these smart rocks under contract to the Air Force Space Division in Los Angeles. Although some of their elements exist today, the SDI's O'Neill expects that it will be several years before the first smart rocks are ready for testing. He hopes for such tests "as early in the 1990s as possible." To comply with the 1972 antiballistic missile treaty, which forbids tests of space-based ABMs, the smart rocks would be launched by rocket from the ground.

The space-based systems will have to "approach genius intelligence," says O'Neill. The smart rock must be able to home in on a large booster, a post-boost bus, or a warhead. It must track its cold, dark target against a background of space, or the earth itself. Despite the difficult mission, smart rocks represent one of the more credible concepts for defense against missiles in the midcourse phase, and perhaps the post-boost phase as well.

One key to developing such weapons is the use of microchip fabrication techniques to build mechanical systems. For instance, Litton Industries (Beverly Hills, Cal.) and Draper Laboratory (Cambridge, Mass.) have fabricated silicon devices smaller than a match head that precisely measure acceleration; from these data a microprocessor computes the missile's velocity and position. Litton and Draper also have built laser gyroscopes the size of a thumb to keep track of rotation. These systems are inherently reliable because they contain no moving parts. Two laser beams circulate in opposite directions through a loop of optical fibers; rotation of the projectile measurably changes the relative frequencies of the two beams.

To stay small, smart rocks need miniature rocket motors; a set of four such rockets must be no more than a few

inches across. In one design being developed, Aerojet Techsystems etches an intricate network of channels and openings in thin metal platelets, using the mask fabrication techniques of the microchip industry. The platelets are then stacked and welded to give complete sets of rocket motors. Their liquid fuels are stored in small, ring-shaped tanks on board the smart rock. In addition to packing more power than solid propellants, liquid fuel allows the rockets to be easily turned on and off.

A defense system's last chance comes when the cloud of warheads and decoys reenters the atmosphere. Discrimination now becomes easier: Heavy warheads glow brightly from aerodynamic heating, while balloons and other lightweight decoys slow down and lag behind. The warheads, however, are now less than a minute from their targets. Moreover, they may be "salvage-fused," rigged to detonate if intercepted. During this terminal phase, the margin for error is very slim.

Kinetic-energy weapons for terminal defense are the most mature of strategic defense technologies. Indeed, they represent an extension of the antiballistic missile technology of the 1960s and early 1970s. During those years, the Army developed two nuclear-tipped ABMs: the Spartan, designed to strike attacking missiles at a range up to 600 kilometers, and the smaller Sprint, capable of very high acceleration and able to provide a final layer of defense as the warheads descended to within 35 kilometers of the ground. Deployment of these weapons was restricted under the ABM treaty.

The Army's ballistic missile defense program (Huntsville, Ala.) is developing kinetic-energy analogs of the Sprint and Spartan. The new weapons will have greatly improved guidance systems, allowing them to score direct hits rather than the near misses that formerly called for the use of nuclear warheads. In addition, the homing vehicles' guidance and propulsion systems are to be greatly miniaturized, allowing the defensive missiles to be built in small sizes. That would make them less costly to build and deploy in large numbers, in the event a decision were made to abrogate the ABM treaty.

The counterpart to the longer-range Spartan is the Exoatmospheric Reentry Vehicle Interceptor System (ERIS), being developed principally at Lockheed (Sunnyvale, Cal.). In ERIS, the tracking problem is as simple as it ever gets. The antimissile has plenty of time to get into space—two minutes or more—and it has to deal with only one kind of target, a hot reentry vehicle seen against the cold background of space. The Army hopes to buy such missiles, with infrared tracking systems, for less than $1 million each.

The Army's kinetic-energy descendant of Sprint—the High Endoatmospheric Defensive Interceptor (HEDI)—is proving a tougher challenge. HEDI must track warheads that have avoided ERIS and attack them at the greatest possible distance—probably 15 to 50 kilometers—to minimize damage from a salvage-triggered nuclear explosion. The rockets must reach their targets in just four to ten seconds, thus calling for acceleration in the hundreds of g's and for extremely fast-acting guidance. HEDI's missile will be several times heavier than that of ERIS, the extra weight coming from the additional fuel needed to overcome atmospheric drag at the rocket's extremely high speeds.

Today's experimental railguns cannot fire multiple shots in quick succession—a crucial requirement.

The Army is developing some of the technology needed for terminal defense under its Small Radar-Homing Interceptor program. In tests planned for New Mexico's White Sands Missile Range, a missile built by LTV Aerospace will be launched against rocket-propelled targets simulating reentering warheads. The LTV missile carries a 13-kilogram radar tracker built by Rockwell International Autonetics (Anaheim, Cal.).

While no laser has yet destroyed a ballistic missile in flight, there has already been at least one successful test of a terminal-phase kinetic-energy weapon. On June 10, 1984, in an experiment called Homing Overlay, the Air Force launched a Minuteman ICBM with a dummy warhead. Twenty minutes later, the Army launched an interceptor missile from Kwajalein Atoll, 7800 kilometers away. The interceptor homed in on the warhead's infrared radiation and struck its target head-on, more than 150 kilometers up and at a closing speed above 6 km/s. The impact strewed fragments across an area of 40 square kilometers.

In 1972, when the ABM treaty was negotiated, there were no likely technological prospects for destroying missiles during their boost or midcourse phases. As a result, both the U.S. and the Soviet Union shared the view that terminal-phase interceptors like ERIS and HEDI could not remain effective, because they could always be overwhelmed by a sufficiently powerful attack, or fooled by decoys. Thus the agreement to ban wide-scale deployment of terminal-phase defense missiles came with relative ease: Neither side thought it was giving up much of value. Today, strategic defense planners hope that some mix of directed-energy and kinetic-energy weapons will greatly thin out an attacking salvo of missiles, destroying most of them in the minutes just after launch. ERIS and HEDI would then face a greatly diminished threat, consisting only of those warheads and decoys that had escaped destruction in early phases.

Because they are more mature than beam weapons, kinetic-energy weapons could well serve as the basis for an initial missile defense system, which might be in place around the year 2000 if the administration prevails over its critics in Congress and in the scientific community. Such a system would probably include antimissile interceptors for terminal defense, along with orbiting rockets deploying smart rocks. This shield could then be stiffened in later years with technologies such as lasers and orbiting railguns, assuming that they pass muster. □

T. A. Heppenheimer, a writer in Fountain Valley, Cal., has a Ph.D. in aerospace engineering.

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PERSPECTIVES

MIT offers R&D internships in Japan

It is not unusual to see researchers from Japan working and studying in U.S. laboratories. Much rarer is the reverse: American technologists who can speak Japanese and who have spent some time in Japanese R&D centers. If MIT and a handful of other American universities are successful, however, a more balanced relationship may eventually replace what has largely been a one-way street.

"Our aim is to train the first generation of technologically sophisticated Americans who will have an understanding and appreciation of Japanese language and culture," says Richard Samuels, director of the MIT-Japan science and technology program. "Whether we compete or collaborate with Japan, we should do so as equals," he adds. Thus, students in MIT's program are required to take the equivalent of two years of language training and a one-year seminar introducing them to Japanese culture before they live and work in Japan.

Initiated in 1981, the program has sent some 35 students for internships of a year or more at Tokyo and Kyoto Universities, national laboratories, and such private firms as NEC, Toshiba, Hitachi, and Matsushita. The program also supports faculty research on Japan—one project studied the recruitment and utilization of engineers by Japanese computer manufacturers—and sponsors workshops designed to bring information on Japanese science and technology to American businesses and government.

But why would students caught up in the demanding coursework of a school like MIT want to tackle a difficult language and interrupt their education to live abroad? Most of the interns have a straightforward professional reason: That's where the action is. Japan is now a world-class arena for research in a variety of fields. For Mark Green, now completing a PhD in materials science, "Japan is the place to go to learn about high technology ceramics." He is preparing to join the staff at the Hitachi Research Laboratory in Hitachi City, where he will live in a company dormitory.

Nor does the experience hurt interns' subsequent employment prospects. "Learning about Japanese technology from the inside gives these students experience that is crucial to American companies," says Patricia Gercik, coordinator of the MIT program. For example, Steven Cohen, an electrical-engineering student at MIT before he went to Japan, is now employed by Teradyne in Boston to work on a laser system used in the production of memory chips. Because the biggest market for such equipment is in Japan, Cohen anticipates being transferred to Teradyne's Japan office to oversee pilot testing of his company's product in Japanese firms.

But what's the incentive for Japanese companies to participate in the program? Their own self-interest, says Samuels. "They understand the consequences if certain imports or foreign researchers are excluded from the U.S. This is one way that Japan can be less parochial than in the past; indeed, *kokusaika* (internationalization) is now a byword in the Japanese business community." In any case, technically knowledgeable interns from a prestigious institution like MIT are eagerly sought in their own right.

Japanese language and orientation programs for science and engineering students are also available at Lehigh, New York University, North Carolina State, and the University of Wisconsin. And Samuels and his colleagues are encouraging those in charge of Japanese language courses within liberal arts curricula to actively seek enrollment from science and engineering students. □ ***—Dennis Livingston***

Tractor radar helps farmers reap profits

By using radar to learn how fast their tractors are moving, farmers are suddenly saving large sums of money. Previously it was impossible to measure the true speed of a tractor in the field, since tires slipping through loose soil would fool conventional speedometers. Now a crop of microprocessor-controlled systems are bringing new efficiency to agriculture, simply by metering ground speed.

Radar sensors have been available for several years from spray-equipment maker DICKEY-john (Auburn, Ill.) and tractor maker J. I. Case (Racine, Wis.). Now the radar concept has the sanction of the industry leader: This year Deere & Co. (Moline, Ill.) will begin shipping its Performance Trak radar sensor, a microwave transceiver contained in a 5×7–inch cylinder that mounts on the bottom of any tractor. The units beam microwave pulses

A radar ground-speed sensor, behind front tire, provides data for increased economy, less wear, and more precise chemical application.

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at the ground and measure the signal that bounces back. The difference between the frequency of the echo and the transmitted beam (the Doppler shift) tells how fast the tractor is moving.

One important reason to monitor ground speed is to check how much the tractor's wheels are slipping. The amount of slippage is controlled by adding or removing ballast. If a tractor is weighed down so much that its tires bite into the soil without any slip, the extra weight strains the drivetrain and wears out the tires, and the increased rolling resistance sends fuel consumption skyrocketing.

Conversely, with too little ballast—allowing too much slip—"the farmer is using his fuel energy to tear up his tires rather than do any productive work," says Arnold S. Farber, manager of electronic engineering at Deere's Product Engineering Center (Waterloo, Ia.).

Radar units provide an instant readout of wheel slippage by comparing wheel speed (measured with a standard magnetic sensor that counts rotating gear teeth in the transmission) to ground speed, and computing the difference. With wheel slip displayed on the dashboard, a farmer can adjust implement load, change the throttle position, or shift gears to keep the tractor running most efficiently. He can thus compensate on the spot for changing soil conditions or to account for varying loads.

Radar sensors may soon be tied to tractor control to maintain optimum traction, predicts TRW, whose Transportation Electronics Division (Farmington Hills, Mich.) makes the Case device. For example, a microprocessor with wheel-slip data could automatically engage front-wheel-drive assist on tractors equipped with part-time four-wheel drive.

Case estimates that the efficiency gains made possible by controlling wheel slip may save as much as $1 per acre as the tractor prepares the soil for planting each season. (Typical farms have several hundred to several thousand acres.) And radar's benefits don't stop there. For example, reliable data on the tractor's ground speed also permit more precise spacing of seeds during planting. The quickest payback, however, probably comes when radar is used to assist in agricultural spraying.

Spraying accounts for one of the greatest costs of agricultural production, says William P. Simpson, product information specialist for Case. Cotton growers, for example, may spray as often as 20 times per year, and chemicals must be applied in precise dosages. Too little is ineffective; too much is not only wasteful but possibly damaging to crops and the environment. But spray rate depends on vehicle speed. Without reliable ground-speed sensors, farmers have had to rely on guesswork, sometimes applying much more chemical than necessary. Case claims its $500 radar sensor saves an average of $4–$5 per acre when used for chemical spray control.

Currently the radar systems are being installed mainly on large tractors, which are already equipped with the sophisticated electronic controls and displays needed to support the sensors. Farmers are ordering radar on over half of Case's large (over 95-horsepower) two-wheel-drive tractors and on more than 80% of the company's four-wheel-drive vehicles. Deere expects to equip about a quarter of its large tractors with the $500–$900 option in its first year. "Every farmer in the world is going to have radar someday," says Simpson. □ ***—Jeffrey Zygmont***

Flying eye clinic spreads surgical know-how

For the past four years, a unique airborne clinic called Project Orbis has carried advanced eye-care technology around the world. But what sets the program apart from other such efforts in the U.S.—Project Hope, for example, and International Plastic Surgery—is that Orbis goes beyond immediate care. By supplying local eye specialists with donated equipment and hands-on medical training, the nonprofit clinic also provides for such care on a continuing basis. Created by David Paton, a Houston eye surgeon, and funded by the U.S. Agency for International Development, the flying surgical suite has now completed 58 tours to 37 countries, including China, Turkey, Thailand, the Philippines, Kenya, and Pakistan. As a result, more than 3500 patients have received sight-restoring operations aboard the aircraft, and some 3800 physicians worldwide have learned new eye-surgery techniques.

Orbis's primary objective is to provide medical training that in many cases is simply unavailable to physicians outside the U.S. (Even if a physician can afford to travel and stay in the U.S., he or she is prohibited by law from performing or assisting in operations unless certified.)

The Orbis clinic is a DC-8 jetliner (donated by United Airlines), which has been turned into a modern operating room fitted with such tools as a laser and a Zeiss ophthalmological operating microscope. The physician-

Orbis surgeons instruct Spanish colleagues in an eye operation aboard the project's plane at Madrid's Barajas Airport.

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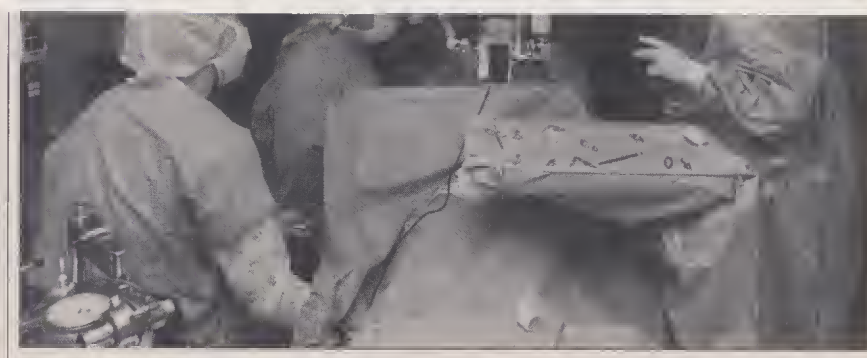
wheel slip may save as much as $1 per acre as the tractor prepares the soil for planting each season. (Typical farms have several hundred to several thousand acres.) And radar's benefits don't stop there. For example, reliable data on the tractor's ground speed also permit more precise spacing of seeds during planting. The quickest payback, however, probably comes when radar is used to assist in agricultural spraying.

Spraying accounts for one of the greatest costs of agricultural production, says William P. Simpson, product



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training function is complemented by donated television equipment that broadcasts the procedures to classrooms on board and outside the plane; operations are also taped and distributed as technical reference materials. Manned by 20 professionals—including nurses, technicians, recording specialists, volunteer pilots, and volunteer physicians who are sometimes specifically requested by the host country—the clinic took off on its first mission to Panama City in 1982 and hasn't stopped since.

While Orbis's primary mission is to impart surgical skills, it is often necessary to provide equipment as well. In Thailand, for example, local physicians learned new methods of performing vitrectomies (operations to remove diseased gel from inside the eyeball). But there was concern that once Orbis left, local surgeons would be unable to perform the procedure because they lacked a costly, sophisticated device called a Grieshaber pump.

"The retina is like a collapsed parachute in water," says Jay A. Fleischman, an ophthalmologist at Bethesda Eye Institute (St. Louis) who served with Orbis in Thailand. "After removing the inner gel, we use this pump to fill the retina with air or sulfur hexafluoride gas; that pushes the retina back into a normal position, ensuring better reattachment." Fleischman helped build an inexpensive substitute for the device, using a $4 aquarium pump, some tubing, an air-pressure gauge and air filter, and a needle to deliver the air to the eye. Retinal reattachment is now a routine procedure in Thailand, according to Fleischman.

Orbis's approach is not without its limitations, however. Many areas are still beset by a lack of such fundamental resources as eye banks and basic surgical equipment. And the relatively high cost of treatment can put it beyond the means of many patients. Still, Orbis can often play a helpful role in these cases. In Bangkok, for example, staffers are working with Thai and American companies to arrange for local, low-cost production of intraocular lenses (tiny plastic discs that replace diseased natural lenses) that would benefit many of Thailand's 400,000 cataract patients.

Ultimately, Orbis functions on many levels at once, says executive director Oliver Foot: "We think of it as a means of not only providing modern eye care but also promoting communication and cooperation among nations." □ —*Helen Wheeler*

RESOURCES

Information sources for topics covered in our feature articles

Micros get graphic, p. 18

Contacts

National Computer Graphics Assn., 8401 Arlington Blvd., Fairfax, VA 22031, (703) 698–9600.

Special Interest Group on Computer Graphics, Assn. for Computing Machinery, 111 East Wacker Dr., Chicago, IL 60601, (312) 644–6610.

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"Forward-looking VDI." Steven Armburst & Ted Forgeron. *PC Tech Journal,* Sept. 1985. Discusses the GSS implementation of VDI; written for programmers.

Colophon. Adobe Systems, 1870 Embarcadero Rd., Palo Alto, CA 94303, (415) 852–0271. Quarterly newsletter about PostScript products.

The Standard. Graphic Software Systems, 9590 SW Gemini Dr., Beaverton, OR 97005, (503) 641–2200. Newsletter about the GSS version of VDI.

Ultrafast chips at the gate, p. 28

Contacts

Semiconductor Equipment and Materials Inst., 625 Ellis St., Suite 212, Mountain View, CA 94043, (415) 964–5111.

Semiconductor Industry Assn., 5320 Stevens Creek Blvd., Suite 275, San Jose, CA 95129, (408) 246–1181.

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Gallium Arsenide Technology. D. K. Ferry, ed. New York: Howard W. Sams & Co., 1985.

"Recollections and reflections of MOCVD." H. M. Manasevit. *Journal of Crystal Growth 55* (1981), 1-9. A pioneer of the process muses on its promise and problems.

"Dynamite diodes." P .S. Cross, R. R. Jacobs, & D .R. Scifres. *Photonics Spectra,* Sept. 1984. Quantum-well lasers.

"Japanese firms take a shine to MOCVD process." C. L. Cohen. *Electronics Week,* Nov. 26, 1984. Laser making at Sony and Toshiba.

"Multilayer avalanche photodiodes and solid-state photomultipliers." Federico Capasso. *Laser Focus/Electro-Optics,* July 1984. Better light sensors through bandgap engineering.

Engineering without paper, p. 38

Contacts

Technology and Business Communications, Inc., 730 Boston Post Rd., Sudbury, MA 01776, (617) 443–4671. Publishers of *The S. Klein Newsletter on Computer Graphics* (twice monthly, $155/yr.) and *The S. Klein Directory of Computer Graphics Suppliers* ($60/vol.).

Society for Computer Applications in Engineering, Planning and Architecture (CEPA), 15713 Crabbs Branch Way, Rockville, MD 20855, (301) 926–7070.

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Computer Graphics World, 1714 Stockton St., San Francisco, CA 94133, (415) 398–7151. Monthly covering CAD hardware and software.

Doing CAD on a Personal Computer. Krouse & Associates/Technology and Business Communications, 1985. Covers history of PCs for CAD, benefits and pitfalls of systems, hardware and software required, networking concepts, buying tips, and descriptions of available vendor products (with comparison charts). Glossary. A second volume is a study covering market size, vendor postions, sales.

Computer Aided Engineering. Penton Publishing, 1111 Chester Ave., Cleveland, OH 44114, (216) 523–6652. Monthly magazine aimed at engineers and managers. Covers use of computer graphics in mechanical and electronic design, manufacturing, architecture, and mapping.

CAD/CIM Alert. Management Roundtable Inc., 824 Boylston St., Chestnut Hill, MA 02167, (617) 232–8080. Monthly newsletter about computer-aided design and computer-integrated manufacturing. $148/yr.

Machine tool industry, p. 48

Contacts

National Machine Tool Builders Assn. (NMTBA), 7901 Westpark Dr., McLean, VA 22012, (703) 893–2900.

Computer Automated Systems Assn., Society of Manufacturing Engineers, One SME Drive, PO Box 930, Dearborn, MI 48121, (313) 271–1500.

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The Competitive Status of the U.S. Machine Tool Industry, 1983. Office of the Foreign Secretary, National Academy of Engineering, 2101 Constitution Ave., NW, Wash., DC 20418, (202) 334–3200.

Economic Handbook of the Machine Tool Industry, 1985. NMTBA.

American Machinist, McGraw-Hill, 1221 Avenue of the Americas, New York, NY 10020, (212) 512–2000. $38/yr.

"A machine tool dynasty." Susan Chira. *New York Times,* Sept. 5, 1985. Profile of a leading Japanese machine tool manufacturer.

TURNING MICROS INTO MAVENS

Availability on PCs should give expert-system software a sharp boost

The commercialization of artificial intelligence (AI) has been fueled during the past two years by the appearance of expert systems—programs designed to store the knowledge and mimic the decision-making capabilities of human experts. Originally available for use only on large mainframe computers or LISP machines (specialized computers designed to run an AI programming language), effective expert systems can now be developed and run on personal computers. As a result of these products' wider availability, DM Data (Scottsdale, Ariz.) estimates that sales of expert systems and programming tools will rise from $74 million in 1985 (11% of the total $700 million AI market) to more than $800 million by 1990. At that time, these products should represent 20% of a $4 billion AI market, constituting the largest software segment of the industry.

An expert system incorporates two integrated elements: a "knowledge base" consisting of computer-encoded information about a specific subject, and an "inference engine" program for manipulating information in the knowledge base using "if/then" statements and other rules of logic. An inference engine and supporting software for entering and displaying information can also be packaged as a separate product and used as a framework, or shell, for creating expert systems. Such software saves customers the time and effort required to write their own rule-based programs, and thus facilitates the development of expert systems. Shell packages, in fact, make up most of the current market for personal computer AI products.

by Howard K. Dicken

While shells for personal computers do not have a complete range of inference capabilities and typically cannot handle a large number of rules, companies have used them to develop customized, in-house expert systems in equipment maintenance, financial analysis, product design, and process control. Software vendors are expected to expand the market for shells by using them to produce relatively cheap, application-specific expert-system software. Shell programs available for $100–$500 can be used primarily to train individuals in applying expert systems; programs costing $500–$2000 are capable of both training and developing small working applications. At the mainframe level, shells may cost up to $60,000.

A few large corporations, including Texas Instruments and McGraw-Hill, offer expert-system products for micros. But most of the companies serving this market are small, privately held firms such as Teknowledge (the leading player), Human Edge Software, Level 5 Research, Radian, and Software Architecture & Engineering. There are also several innovative public companies attempting to carve out a niche in this field. These include ExperTelligence (Santa Barbara, Cal.), IntelliCorp (Mountain View, Cal.), and Migent Software (Scottsdale, Ariz.). Investors should keep in mind that the large capital requirements for R&D and advertising budgets have so far kept most AI firms from making a profit.

ExperTelligence (OTC: EXPR), initially a developer of educational software and computer camps, has been providing an expert-system shell and versions of the LISP and Prolog AI programming languages for the Apple Macintosh since 1983. The firm is banking on its belief that such Macintosh features as high-resolution graphics, windows, menu-driven instructions, and mouse pointers are similar enough to those of the higher-priced LISP computers to make the Macintosh the best machine for delivery of AI software on personal computers.

On the basis of its software products, revenue in fiscal 1985 was $834,000, compared with no income in 1984. Losses in 1985 were $411,000, compared with $713,000 the previous year; the loss per share also decreased, from .012¢ in 1984 to .006¢ in 1985. While the loss-per-share figures appear extremely low, investors should note that the company has issued almost 63 million shares of outstanding stock—an unusually large number.

IntelliCorp (OTC: INAI), founded in 1980, is one of the oldest and best-established companies in the AI market. IntelliCorp sells AI software to the biotechnology industry and a $30,000 shell system called Knowledge Engineering Environment (KEE) for use on LISP machines and Digital Equipment's VAX minicomputers. The company has introduced PC-Host, a program that allows expert systems developed with KEE to be accessed by an IBM PC (with the larger machines still acting as a host). Although KEE itself cannot be modified at the PC level, PC-Host represents an important step by an expert-system company to enable PC users to apply large programs.

Sales in fiscal 1985 were $8.7 million, with a loss of $724,000, for a loss per share of 14¢. Sales the previous year were $2 million; losses were $1.7 million, for a 41¢ loss per share.

An expert system originally developed by Transform Logic for mainframes and rewritten for personal computers was recently purchased by **Migent Software** (Vancouver: MSC). This product, called Enrich, helps nonprogrammers generate custom-configured programs such as databases, spreadsheets, and forms. Enrich advises users on the sequence of commands needed to set up the desired program. It then converts those commands to the corresponding machine code. Enrich, priced at $595, is available for IBM PCs and compatibles. Migent does not plan to make its product available for home use; it is targeted to corporate accounts and to computer stores oriented to business sales.

Migent did not begin operations until 1985. No sales were reported for that fiscal year; losses were $426,000, with a 7¢ loss per share. □

Howard K. Dicken is president of DM Data, a market research firm specializing in artificial intelligence.

TECHSTARTS

Celerity Computing:
STREAMLINED CODES BOOST COMPUTING SPEED

Tasks such as molecular modeling, mechanical stress analysis, and image processing require so much number crunching that even the most powerful computers can seem slow. One way of speeding things up is to streamline the internal codes that instruct a computer to perform its most basic functions. Celerity Computing—as well as a growing number of competitors including Pyramid Technology and Hewlett-Packard—has designed machines based on such a reduced instruction set computer (RISC) architecture. The market Celerity is targeting with its 32-bit multiuser systems is computationally intensive engineering applications for mechanical design, such as computer simulation of objects undergoing vibration or stress.

Celerity will target computer-aided engineering, says president Steven Vallender.

Financing: $17 million in venture capital from investors including Hambrecht & Quist Partners, Rainier Venture Partners, Oxford Ventures, John Hancock Venture Capital Fund, Southern California Ventures, Jamieson & Co., and Charles River Partnerships.

Management: Founders Stephen Vallender (president), Nicholas Aneshansley (VP of hardware engineering), and Andrew McCrocklin (VP of software engineering) helped manage development of a 32-bit microprocessor chip set for NCR at its San Diego manufacturing plant. Vallender was director of engineering, Aneshansley was chief of advanced development, and McCrocklin headed an application development team.

Location: 9692 Via Excelencia, San Diego, CA 92126, (619) 271-9940.

Founded: May 1983.

Private Satellite Network:
ONE-WAY CORPORATE TV BROADCASTS

The "videoconference," in which far-flung participants meet face-to-face via TV, has been slow to catch on because it is costly to install transmission equipment at each site. Now, Private Satellite Network (PSN) and competitors such as VideoStar Connections offer a more affordable alternative: one-way broadcast video.

A company with many branch offices, for instance, can construct one studio for filming and transmitting of presentations, while installing only receiving equipment at the branches. Because the networks will use signal boosters designed originally for the "direct-broadcast satellite" method of delivering entertainment programming, transmissions are strong enough to be picked up by small, low-priced dish antennas. PSN's customers already include J. C. Penney; Ford, Merrill Lynch, and the U.S. Army.

Financing: $18 million in venture capital from investors including Oak Investment Partners; New Enterprise Associates; Rothschild, Unterberg, Towbin; Merrill Lynch Ventures; Welsh, Carson, Anderson & Stowe; Warburg, Pincus; J. C. Penney, and General Instrument.

Management: G. William Miller, chairman, is a former Secretary of the Treasury and Federal Reserve Board chairman and was previously chairman of Textron. Marc Porat, president and CEO, was executive director of the Aspen Institute, a management research organization. Gary E. Lasher, COO, was corporate VP of communications and engineering for Continental Telecom.

Location: 215 Lexington Ave., New York, NY 10016, (212) 696-9476.

Founded: August 1982.

Focus Technologies:
TAILOR-MADE FITNESS PROGRAMS

Our society's increased emphasis on fitness is drawing more and more people into diet and exercise programs. But, for many individuals, it could be risky to embark on such regimens without taking certain precautions. Focus Technologies is developing a battery of blood tests that will employ genetic and biochemical markers to determine individual risk factors. Results can then be used to create personalized health programs. The company's target market will include the group health-insurance policyholders of Equitable Life Assurance, which will be testing a pilot program on 5000–10,000 people later this spring, as well as corporate fitness programs, hospitals, and health maintenance organizations. Although Focus will initially license markers and testing kits from other biotechnology companies, it may eventually build its own lab to develop such materials.

Financing: Several million dollars in venture capital from the Equitable Life Assurance Society and TEI Industries, a venture capital firm.

Management: Nelson Schneider, CEO, is also managing director of TEI Industries. He helped found California Biotechnology and previously was senior health care analyst for E. F. Hutton. Zsolt Harsanyi, chief scientific consultant, was chairman of the genetics department at Cornell University Medical Center. Sanford Greenberg, chairman, was a founder of Educational Computer Corp. and Healthcare Systems.

Location: 600 New Hampshire Ave., NW, Washington, DC 20037, (202) 342-6262.

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